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consequences for OHS and productivity

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LEAN IN THE READY-MADE GARMENTS SECTOR IN BANGLADESH

CONSEQUENCES FOR OHS AND PRODUCTIVITY

BY
ABU HAMJA

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AALBORG UNIVERSITY
DENMARK

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Dissertation submitted November 6, 2019

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ENGLISH SUMMARY

This PhD dissertation was a part of the POHS-BD project. The overall objective of this thesis is to contribute to the knowledge of the application of lean tools and its effects on productivity by integrating occupational health and safety (OHS) into the ready-made garments (RMG) sector in Bangladesh. Presently, an ongoing argument exists in the literature concerning whether productivity and OHS are complementary or contradictory. Thus far, the literature has indicated that lean thinking is an open and ambiguous concept for understanding the two perspectives of productivity and OHS, which depend on the lean application process and context. In particular, the relationship between lean, OHS, and productivity is undergoing extensive research in the RMG industry, particularly concerning repetitive and intensive assembly work. This thesis addresses this gap by answering the following research questions:

- Are productivity and OHS contradictory or complementary in the garments industry?

- What is the relationship between lean tools and effects on productivity and OHS in the RMG sector?

- What are the effects of lean application on workers' health in the garment industry?

- What are the transfer mechanisms for successful lean application in the RMG sector?

This thesis is a synopsis and discussion of four sequential studies that were performed to contribute to answering the abovementioned research questions. Each of these four studies is described in the following paragraphs:

The main objective of Study I was to identify the management practices of productivity and OHS in the Bangladeshi RMG sector, which was crucial before taking any intervention initiatives to improve both. Therefore, the study focused on 50 factories' baseline data related to the maturity levels of their productivity and OHS practices. The results showed that a factory with a higher level of maturity in productivity was likely to have a high level of maturity in OHS practices and vice versa, as in developed countries. Study I investigated the correlation of the effect of plant size on the presence of both dimensions. The results showed a statistically significant correlation for large plant, marginal significance for medium size and not significant for small factories.

Study II reviewed the literature on lean and OHS in the RMG sector. The literature had four characteristics: it was limited, there was a shortage of qualitative materials,

many of the studies were case studies or pilot phase implementations, and there were limited empirical articles. A research gap was found in that repetitive strain injuries and musculoskeletal disorders in the lean environment of the RMG sector remain unexplored. Furthermore, sustainable lean applications in the RMG sector were not found in the literature in this sector. To understand the possibilities for the sustainable application of lean, mechanism studies must be conducted.

Study III mainly examined the lean tools intervention process through integrating OHS and ergonomics into six garment factories. The intervention results showed that three lean tools (Time and Motion Studies, 5S, and value-stream mapping) had positive effects on efficiency improvements as well as statistically significant improvements of MSD pain in workers. Negative health effect symptoms such as muscular pain and fatigue were not found within workers after the intervention. Therefore, these intervention results indicated that without significant effects on workers' health in the short term, lean is applicable with OHS integration in the RMG sector.

Study IV contributes to re-understanding how to implement lean in garments. I did this by analyzing the transformation mechanism of lean in the developing context, specifically in the RMG sector. In addition, I analyzed how lean can be implemented in an effective manner. In this study, I used the CIMO (Context, Intervention, Mechanism, and Output) concept to find the optimal mechanisms underlining five local success factors for achieving the best output. These five local success factors were top management commitment, worker involvement and participation, training, tools and methods, and learning culture. The analysis of mechanisms had points of departure in the main factors that are usually recommended for lean application; however, the literature rarely specifies how they can be implemented in practice. This study's analysis of mechanisms showed that 23 mechanisms can facilitate the aforementioned five factors, including top management personnel conducting floor visits every day, worker empowerment, and offshore training. In four case factories, the results indicated that one medium-size factory was the most successful and one large factory was in the medium range of success. In addition, this study presents a conceptual model for sustainability.

Taken together, the findings of this thesis contribute to the growing body of knowledge on lean tools' impact on productivity and OHS consequences. They do so through providing empirical findings on interventions as well as by providing lean transformation mechanisms and a conceptual model for sustainability. Furthermore, this thesis shows that it is possible to initiate lean without physical harm to workers. More crucially, this thesis demonstrates a systematic method for lean intervention in the RMG sector, which will be helpful for academicians as well as practitioners.

DANSK RESUME

Denne ph.d.-afhandling er en del af POHS-BD-projektet. Det overordnede mål med denne afhandling er at bidrage til viden om anvendelse af lean værktøjer og deres virkninger på produktiviteten og arbejdsmiljø beklædningsindustrien (ready made garment (RMG)) i Bangladesh. Der findes en løbende diskussion i litteraturen om sammenhængen mellem produktivitet og arbejdsmiljø – i hvilken udstrækninger de komplementære eller modstridende. Litteraturen indikeret at lean er et åbent og tvetydigt begreb og konsekvenserne for henholdsvis produktivitet og OHS afhænger af konteksten og implementeringspraksis. I øjeblikket foregår der især en forskningsmæssig diskussion af forholdet mellem lean, arbejdsmiljøs og produktivitet inden for beklædningsindustrien. Det gælder specielt for konsekvenserne af ensidigt gentaget arbejde ved syning. Denne afhandling bidrager til at afklare denne diskussion ved at besvare følgende forskningsspørgsmål:

- Er produktivitet og arbejdsmiljø modstridende eller komplementære i beklædningsindustrien?

- Hvad er forholdet mellem anvendelsen af lean værktøjer og effekter på produktivitet og arbejdsmiljø i beklædningsindustrien?

- Hvilke effekter har anvendelse af lean på arbejdstageres helbred i beklædningsindustrien?

- Hvilke mekanismer kan anvendes til at skabe en vellykket lean-anvendelse i beklædningsindustrien?

Denne afhandling består af en sammenfatning og diskussion af fire sekventielle undersøgelser, der er udført for at bidrage til besvarelsen af ovennævnte forskningsspørgsmål. Hver af disse fire undersøgelser er beskrevet i de følgende afsnit.

Hovedmålet med undersøgelse I var at identificere ledelsespraksis for at styre produktivitet og arbejdsmiljø i beklædningsindustrien i Bangladesh, hvilket var væsentligt for at kunne tilrettelæge interventionsinitiativer til forbedring af begge områder. Undersøgelsen omfattede 50 fabrikker hvor vi indsamlede baseline data om deres styring af produktivitet og arbejdsmiljø. Data blev brugt til at vurdere modenhed (maturity) af deres praksis. Resultaterne viser at en fabrik med et højere modenhedsniveau i styring af produktivitet sandsynligvis også vil have et højere modenhedsniveau for arbejdsmiljø og vice versa. Det svarer til resultater fundet i de industrialiserede lande hvor der også er fundet en tæt sammenhæng mellem produktivitet og arbejdsmiljø. Resultaterne viser endvidere en sammenhæng mellem virksomhedsstørrelse hvor sammenhængen mellem produktivitet og arbejdsmiljø er

statistisk signifikant store virksomheder, af marginal betydning for mellemstørrelsen og ikke signifikant for små virksomheder.

Undersøgelse II omfatter et litteratur review af sammenhængen mellem lean, produktivitet og arbejdsmiljø i beklædningsindustrien. Litteraturen viste at have en række generelle begrænsninger: der var kun få undersøgelser, næsten ingen dybdegående kvalitative undersøgelse, de fleste undersøgelser omfatter casestudier af pilotprojekter, og endelig var der få artikler med stærkt empirisk materiale. Med disse forbehold viser resultaterne en positiv sammenhængen mellem lean og produktivitet. For arbejdsmiljøet blev der ikke fundet tendenser til negative effekter på arbejdsmiljø og helbred, men der var dog kun få undersøgelser og nogle pegede også på muligheden for både positive og negative konsekvenser.

Undersøgelse III omfatte intervention i seks virksomheder med introduktion af lean værktøjer integreret med forbedring af arbejdsmiljøet. Interventionsresultaterne viser at tre værktøjer (tids- og metodestudier, 5S og value stream mapping) havde positive effekter på forbedring af produktiviteten såvel som forbedring af arbejdsmiljøet. Negative sundhedseffekter som muskelsmerter og træthed blev ikke fundet hos arbejdstagerne efter interventionen, men tværtimod statistisk signifikante reduktion af muskel-skelet træthed og smerter hos arbejdstagere. Interventionsresultater indikerer således at der tilsyneladende ikke er væsentlige negative effekter på arbejdstagernes helbred på kort sigt ved anvendelse af lean med integreret fokus på arbejdsmiljøet, men der er behov for langstidsstudier i beklædningsindustrien.

Undersøgelse IV bidrager til at forstå hvordan man i praksis kan implementere lean i beklædningsindustrien. Det gjorde jeg ved at analysere mekanismerne for lean transformation for lean i fire virksomheder som deltog i interventionen. I denne undersøgelse brugte jeg CIMO-konceptet (Context, Intervention, Mechanism and Output) til at finde de optimale mekanismer at opnå det bedste output. Mekanismerne kan sammenfattes under fem overskrifter: topledelsens engagement, medarbejderinddragelse, træning, praktisk anvendelse af værktøjer og udvikling af en læringskultur. Analysen af mekanismer bidrager til at specificerer indholdet af disse fem overskrifter som ofte beskrives i litteraturen som afgørende for lean implementering. Det er dog sjældent at de praktiske anvendelse er blevet analyserer. I denne analyse af mekanismer fandt jeg 23 mekanismer der bidrager til at lean kan implementeres i praksis. Fx handler topledelsens engagement om at demonstrere dette engagement i praksis ved at besøg de involverede pilotlinjer og efterspørge resultater fra mellemlederne. Analysen bygger på at en mellemstor fabrik viste sig succesfuld, to have en vis succes og en mislykkedes. Resultaterne peget også på at den vellykkede fabrik havde størst chance for en fremtidig bæredygtig udvikling af lean.

Samlet bidrager resultaterne af denne afhandling til den voksende viden om lean og de mange værktøjers indflydelse på produktivitet og arbejdsmiljø. Det gør den gennem empiriske resultater som bygger på praktiske interventioner i beklædningsvirksomheder i Bangladesh samt ved at identificere mekanismer for lean transformation som kan føre til en mere bæredygtighed implementering. Desuden viser denne afhandling at det er muligt at implementere lean uden negative konsekvenser for arbejdstagerne. Dermed demonstrerer denne afhandling en systematisk metode til lean intervention i beklædningsindustrien som vil være nyttig for akademikere såvel som praktikere.

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This PhD dissertation is a synopsis of the results from four publications submitted to international peer-reviewed journals. The manuscripts are provided in the last part of the dissertation. I conducted a Danish International Development Agency (DANIDA)-funded PhD project from February 2016 to August 2018 at the Department of Materials Science and Production, Aalborg University Copenhagen Campus, Denmark. I used data in my research from the Productivity and Occupational Health and Safety (POHS) project.

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Abu Hamja
November 2019

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CHAPTER 1. INTRODUCTION

After 1970, most transnational apparel brands began outsourcing on a major scale to manufacturing facilities in developing countries. The abundance of cheap labor in those countries influenced buyers to place orders there (Chowdhury, Ahmed, & Yasmin, 2014; Rakib & Adnan, 2015). Some special external influences such as the Multifiber Arrangement (MFA), Generalized System of Preferences (GSP), and Quota services helped the development of this sector in lower-cost production countries (Haider, 2007). As a result, opportunities were created for rural, inexperienced, and young workers to work to earn wages. As they became wage workers, they were also subjected to quite poor working conditions in the factories.

With this, the garments industry became known for its hazardous work environments. When it was still located in industrialized countries, it was already well-established that working in the garment industry constituted a high risk of repetitive strain injury (RSI) (Andersen & Gaardboe, 1993a, 1993b; Buckle & Jason Devereux, 2002; Muggleton, Allen, & Chappell, 1999; Vezina, Tierney, & Messing, 1992). This RSI risk was carried along with the shift of the garment industry to developing countries (Ozturk & Esin, 2011; Sealetsa & Thatcher, 2011).

For the Bangladeshi garment industry, working conditions are not different from those in other developing countries. This sector acts as a source of livelihood by fulfilling the needs of workers, but also represents a risk to the workers' health and wellbeing. Therefore, the workers are dependent on market competitiveness to obtain jobs, and conversely these jobs should offer conditions that can secure the livelihood, health, and wellbeing of workers. The abundance of cheap labour in Bangladesh influenced buyers to place orders there; since 1980, the ready-made garments (RMG) sector has grown to become the backbone of the country's exports and principal source of foreign currency (Chowdhury et al., 2014; Rakib & Adnan, 2015). Bangladesh, with a worldwide market share of 6.5%, is establishing a strong position as the next RMG hotspot by taking advantage of China losing its dominance in the RMG sector (Berg, Hedrich, Kempf, & Tochtermann, 2011). The reason for the Bangladeshi RMG industry's success is the privilege of the export quota system as well as low labor costs, brand goodwill, and higher quality of its products (Haider, 2007).

Although booming at an unprecedented rate, the garments industry of Bangladesh faces several challenges that are hampering it from obtaining the results it expects. One study that discussed these challenges and divided them into temporary problems and structural problems (Syed, Ferdous, Hossain, & Ferdous, 2015). Bangladesh faces some structural problems that are related to it being a developing country, such as government policies, transportation, and infrastructure, and these cannot be controlled. However, some temporary problems such as productivity and compliance can be controlled by factories (Berg et al., 2011; Ferdous et al., 2014). Among all these challenges, the present study focused on the productivity, occupational health and safety (OHS), and ergonomics (from compliance) problems faced in the garment industries of Bangladesh.

In the case of both national and international stakeholders, the workplace safety and compliance problems in Bangladesh are gaining increasing attention. Following the tragedy of the Tazrin fashion fire as well as the Rana Plaza incident in Bangladesh, buyers are more concerned about compliance issues before converting any order (Delowar Hossain & Ferdous, 2015). These accidents have shown that large risks exist in the form of building collapse and fires. These accidents have created stronger attention to OHS, and particularly in Bangladesh, national as well as international stakeholders have since pushed for improvements to OHS. In Bangladesh, OHS legislation and labor inspections have been upgraded and international garment brands have formed the Accord and Alliance, which have pushed strongly for improvements. However, all of these actions are from the outside, attempting to enforce garment companies to secure OHS. Such outside actions do not directly influence operations, and factory owners may therefore attempt to make a showpiece for outsiders when they are visiting their factories (Frick, 1990; Hasle, Madsen, Hansen, & Maalouf, 2019). Actions enforcing OHS in garment factories raise the following question: Is it also in a business's interest to guarantee a secure and healthy workplace environment for its workers?

According to international standards, the whole Bangladeshi garments industry has a productivity problem, and the efficiency level of Bangladeshi workers is not high enough. An empirical study compared the efficiency of Bangladeshi workers with that of Chinese workers, and showed that the efficiency of Bangladeshi workers is only one quarter that of Chinese workers (Md. M Islam & Adnan, 2016). In the literature, several possibilities can explain the low productivity compared with China, such as the low literacy rate, the reluctance of RMG owners to invest in any training and development facilities for workers, the poor technological capability, and the concept of continuous improvement not being integrated into the production floor (Berik et al., 2007; M. S. Islam, Rakib, & Adnan, 2016; Kader & Akter, 2014). All of these reasons make the RMG industry in Bangladesh unproductive and hamper it from reaching its peak level of production.

Because of the increased competitiveness in the global market and rise in business costs, the RMG industry in Bangladesh is starting to take measures to improve productivity as well as OHS conditions. To improve operational performance such as productivity, lean is an effective tool. In addition to productivity, lean has the potential to influence workers' wellbeing, health, and safety, because it transforms work systems and work processes (Holden, 2011). Therefore, the application of lean manufacturing is evident in many industries; however, the results of lean application on productivity with OHS integrated have not been studied before in the RMG sector.

The term “lean” was first introduced by Johan Krafcik (1988), and subsequently Womack et.al. (1990) used the term to describe the Toyota Production System (TPS). The main focus of lean is to create value for end customers by eliminating nonvalue-adding activities from the production process (Womack & Jones, 1996). For this reason, numerous services and industrial sectors worldwide adopt lean production everyday (Samuel, Found, & Williams, 2015; Stone, 2012).

Furthermore, lean manufacturing is progressively used in RMG to improve productivity, and research studies have confirmed positive changes in productivity in many RMG industries where lean has been adopted (Quddus & Nazmul Ahsan, 2014; Vijayakumar & Robinson, 2016; G. L. D. Wickramasinghe & Wickramasinghe, 2016; G. Wickramasinghe & Wickramasinghe, 2017). For example, value-stream mapping (VSM) helps identify the various types of nonvalue-adding activities generated within an organization as well as ways to remove this waste (Lingam et al., 2015). Other researchers have noted that some lean tools such as 5S, VSM, and TPM practices have shown encouraging relationships with OHS in the industry as well as manufacturing performance (D. V. Kumar, Mohan, & Mohanasundaram, 2019; Vijayakumar & Robinson, 2016; G. L. D. Wickramasinghe & Perera, 2016).

Moreover, the effects of lean are much more ambiguous in terms of OHS. Various studies have indicated that workers’ physical and mental health constitute a risk that depends on the implementation of lean (Conti, Angelis, Cooper, Faragher, & Gill, 2006; Harrison, 1994; Landsbergis, Cahill, & Schnall, 1999; Stewart et al., 2010). However, later reviews of the literature (see Brännmark & Håkansson, 2012; Hasle et al., 2012) have indicated that both positive and negative effects of lean on OHS exist, but it is crucial to be conscious about the negative effect of lean tools in repetitive assembly work. The RMG process has strong repetitive elements, and therefore, it is critical to consider this issue. Thus far, only few studies in the RMG sector have described the effect of lean on OHS, although case studies exist with unclear results. These studies have mainly suggested that lean can have both positive and negative effects on the health risk of workers (Abeysekera & Illankoon, 2016; Jackson & Mullarkey, 2000).

Thus, bridging this gap between lean and OHS in the RMG sector is a vital concern. The conclusion is pressing on the idea that productivity and OHS must be cogently addressed on the shop floor. To achieving improvements to both productivity and OHS simultaneously, several issues must be considered. Thus far, the relationship is open and ambiguous because assessments of the consequences of lean suggest the outcome of lean application mostly depend on the actual implementation process. If management decide only to focus on efficiency, the result will be impairments of workers’ health; however, management also has the possibility to focus on lean application with an integrated OHS component, thereby achieving both productivity and OHS improvements.

In general, this thesis contributes to the understanding of the extant lean tools applied in the garment industry, including OHS measures and the possible consequences. For this objective, this thesis examines four research questions (RQs), which are provided as follows:

RQ 1: Are productivity and OHS contradictory or complementary in the garments industry?

RQ 2: What is the relationship between lean tools and effects on productivity and OHS in the RMG sector?

RQ 3: What are the effects of lean application on workers' health in the garment industry?

RQ 4: What are the transfer mechanisms for successful lean implementation in the RMG sector?

This thesis builds on four papers that address these four RQs. The RQs are investigated through quantitative and qualitative analyses from the Productivity Occupational Health and Safety, Bangladesh (POHS-BD) project intervention. In this project, lean tools were implemented in 12 Bangladeshi garment factories. The research methodology of this thesis completely followed the POHS-BD project's methodology. The findings are presented in the fourth chapter of this thesis, which are based on the four research articles.

The overall structure of the thesis consists of six chapters, including the present introductory chapter. The remainder of this thesis is organized as follows: Chapter 2 presents and discusses the literature, which covers the challenges faced by the RMG sector in Bangladesh; lean manufacturing with lean as a productivity improvement tool; OHS and ergonomics; and finally integration between lean and OHS. The main knowledge of previous literature regarding this research was published in a review paper (Hamja, Maalouf, & Hasle, 2019b), which partially forms Chapter 2 of this thesis; however, the results of the abovementioned review paper are presented in the findings section. Chapter 3 provides an overview of the methodology and study context, and Chapter 4 includes a description of the findings from four articles; for instance, the present practices of productivity and OHS in the Bangladeshi RMG sector, previous literature and the research gap, the extent of lean practice, and finally the possible mechanism of lean implementation in the RMG sector. Chapter 5 includes a discussion of the findings from the four articles and connects them to the theoretical insights and discussion before and after the results; in addition, this chapter discusses the research implications, limitations, as well as recommendations for practitioners. Finally, Chapter 6 presents the final conclusion of this thesis.

CHAPTER 2. LITERATURE REVIEW

This chapter reviews the present literature on lean in garments, productivity, and OHS. To do so, I start by analyzing the challenges faced by RMG sector in Bangladesh. The major challenges are identified as the productivity and working conditions in RMG factories. Lean could be a possible solution, and therefore, the next step is to discuss the possibilities and present knowledge about lean in garments. In addition, it is necessary to discuss lean production and integrate OHS and ergonomics into the implementation process for enhanced work environments, as well as productivity improvements. The final section of this chapter presents the current knowledge in existing literature of synergies between lean and OHS.

2.1. CHALLENGES IN THE RMG SECTOR

The RMG industry of Bangladesh is facing several challenges for the further development of its production. These challenges can be divided into internal and external challenges. I start by presenting the external challenges, which are generally difficult for industries to control. Subsequently, I examine the internal challenges, which garment factories have a better possibility of controlling, by using lean among others. The foremost external challenges faced by the RMG industry in Bangladesh are related to poor governmental policies, followed by the country’s poor transportation and infrastructure conditions, the energy crisis, a lack of proper raw materials, labor unrest, wage problems, and the fast fashion trend. Literature on each of these external challenges is introduced in the following subsection.

2.1.1. EXTERNAL CHALLENGES

Government policies

Governmental policies of a country play a crucial role in that country’s industrial and economic stability. The garments industry along with other industries suffer in developing countries such as Bangladesh because of political instability. Specifically, because of political unrest, Bangladesh loses orders from US and European buyers (Berg et al, 2011). For example, there were fewer shipments of RMG to the US and EU countries in the year of 2014–2015 (Syed et al., 2015). Furthermore, the political instability, complicated policies, and corrupt administration disrupt the productivity and goodwill of the RMG industry (Hossan, Rahman Sarker, & Afroze, 2012); however, substantial transformations in the RMG sector can be achieved with proper government policies.

Transportation and infrastructure

Poor transportation and infrastructure are other major causes hindering Bangladesh's garment industry from flourishing. Bangladesh is in unfavorable position within South Asia when it comes to its infrastructure condition. Foreign investment interests are often lost because of the country's poor power and energy conditions and substandard sea port facilities (Syed et al., 2015). The most commercially important highway, the Dhaka–Chittagong highway is still underdeveloped and always suffers huge traffic jams. Approximately 300 kilometers of distance often takes 12 hours to cover (Rakib & Adnan, 2015; Syed et al., 2015). In addition, alternative transportation systems such as the railroad show promising capability, yet because of its improper utilization and limited transport capability of 120 containers per day, it is inconvenient for the transportation of products (M. S. Islam et al., 2016; Syed et al., 2015). Another cheap and efficient transportation method is river transportation, but in the case of Bangladesh, this transportation system is lagging behind all other systems. However, the main transportation problem Bangladesh faces is an inefficient sea route and seaport infrastructure. The efficiency of the Chittagong sea port is also limited, which increases the cost (Rakib & Adnan, 2015). Other than Chittagong seaport, Bangladesh has Mongla seaport, but the country lacks a deep seaport, hampering its port activity. The lack of sufficient deep seaports makes the docking of mother vessels impossible (Berg et al., 2011), and thus Bangladesh depends on the use of consignment boats (Syed et al., 2015). Compared with other competitive countries such as Thailand and Sri Lanka, the freight handling charges of Chittagong port are two and three times higher, respectively (Rakib & Adnan, 2015).

Energy crisis

The shortage of gas and electricity hampers the development of RMG industry in Bangladesh. Islam and his colleague (2013) emphasized the losses of export orders due to shortages of electricity and gas. In addition, a previous study explained that because of the lack of a continuous power supply, 30% production capacity has been underutilized in the garment sector. This condition badly affects the industry in the competitive international market. To overcome such a problem and ensure an uninterrupted power supply to the garment factories, the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and the Bangladesh government have implemented several initiatives.

Raw materials

In addition, the import of raw materials from other countries hampers the growth of the RMG industry of Bangladesh. Among all other raw materials, cotton is the most crucial and demanded raw material for the Bangladeshi garment industry, and Bangladesh is one of the world's biggest importers (Syed et al., 2015). The average lead time to source raw materials becomes longer because of over-dependency on imports from foreign countries. Woven fabric imports from India and China eat up 15 and 30 days' additional lead time, respectively (Berg et al., 2011). Finally, for this reason RMG manufacturers often face delivery delays.

Labor unrest and wages

Labor unrest is another factor that hinders the smooth growth of the RMG industry. Ignoring the fundamental rights of workers often leads to labor unrest (Kamal, Billah, & Hossain, 1970; Lima, 2012). Labor unrest causes losses to companies, damages the economy, as well as tarnishes the name of the country abroad (Yunus & Yamagata, 2012). To prevent frequent labor unrest, workers' wages must be increased. However, this increasing trend of labor wages is one of the main challenges to the RMG sector in Bangladesh, a developing country, because it reduces the profit margin. To cope with the increasing trend of labor wages, the RMG industry must adopt new tools to increase the productivity of its factories.

Fast fashion trend

The current fashion trend poses a great challenge to the RMG industry. International market trends require frequent changes in products for the constant growth of the market (Ozdamar Ertekin & Atik, 2015) as well as to satisfy the needs of customers. This trend of current fashion is referred as "fast fashion." Fast fashion can be regarded as a consumer-driven approach that focuses on consumers' demand and fashion sense. To fulfill the demands of fashion-conscious customers, international retailers have adopted the process of introducing new designs to stores within 3–5 weeks (Barnes & Lea-Greenwood, 2006; Bhardwaj & Fairhurst, 2010). Thus, international retailers are putting pressure on manufacturers to adapt to a shorter and more flexible supply chain and manufacturing philosophies, thereby improving efficiency and supplying products within a strict timeline or short lead time (Bhardwaj & Fairhurst, 2010).

In sum, some external constraints are hampering the development of RMG factories. Many of these constraints are out of the control of factories because they cannot do anything about government policies regarding such things as transportation, infrastructure, and energy problems. Instead, factory administrations can focus on their internal setup. Accordingly, in the next section, I present the internal challenges of RMG factories in Bangladesh and how to deal with them.

2.1.2. INTERNAL CHALLENGES

Higher lead time

The abovementioned external challenges influence the decision-making of the RMG industry about its internal challenges. According to the Oxford Advanced Learner's Dictionary, lead time refers to "the time between starting and completing a production process.” In the essence of RMG, this lead time refers to the time necessary for delivering the ordered end products after receiving the garment export orders (Haider, 2007). Hossain et al. (2019) emphasized the importance of lead time with other countries, which is similar to the findings of Kader and Akter (2014), who also emphasized different factors related to higher lead times in strong global competition. In addition, Haider (2007) focused on comparative studies and found, for example, the average lead times for woven and knitted garments products in Bangladesh are 90–120 and 60–80 days, respectively; by contrast, in China it is 40–60 and 50–60 days and in India it is 50–70 and 60–70 days for woven and knitted products, respectively. Several external challenges exist, such as poor transportation, a lack of raw materials, as well as an energy crisis, creating such high lead times for Bangladesh garments. In addition, Rakib and Adnan (2015) emphasized high dependencies on exported raw materials as another reason for these high lead times. However, having such high lead times also depends on internal factors as well as external factors. One of the major internal reasons for the high lead time in the RMG industry is the higher time during production. Because of the lack of proper production planning on the shop floor, operations managers are not able to utilize their full potential, resulting in longer lead times (Kader & Akter, 2014). Therefore, some actions such as redesigning workstations, using some lean tools, improving the work environment on the production floor could possibly reduce lead times significantly.

Productivity

Productivity is a highly critical factor in production performance and as well as for the competitiveness of any garment factory (Abdullah, 2009). Productivity has different definitions and its uses depend on the purpose and types of data that are available. I use the common definition of productivity from Wikipedia, which is as follows: *“The ratio of an aggregate output to a single input or an aggregate input used in a production process, i.e. output per unit of input, typically over a specific period of time” (Wikipedia, 2019, para. 1)*. Thus, measuring productivity involves determining how efficiently a process runs and how effectively it uses resources. In the garment sector, several factors affect how efficiently and effectively processes are run: poor production layout, low skilled workers, poor motivation, job turnover tendency, poor teamwork, fast technological changes, less job satisfaction, high wastage, and inadequate skill development training programs within the company. Before productivity can be improved, these issues must be considered carefully, and very limited research has provided in-depth overviews or any proper solution to solve them. Thus far, some research has given some indication of how to overcome the aforementioned issues, such as production layouts. Furthermore, an effective and efficient management system plays a large role in improving productivity combined with organizational performance (Saha & Mazumder, 2015); furthermore, job satisfaction and working environment can also increase the productivity of any factory (Abdullah, 2005, 2009).

Compliance

To remain competitive in today's global market, workplace safety and compliance are essential for business sustainability (Hoque & Rana, 2019). Today, after some tragic incidents in Bangladesh, compliance issues are the top priority of buyers (Syed et al., 2015). Compliance means to be compliant with certain codes of conduct regarding working conditions, labor relations and welfare, wage and leave issues, building codes, fire emergency requirements, first aid and medical issues, personal protective equipment, maintenance, and any other issues pertaining to the needs of the organization (ILO, 1998, 2016).

Moreover, Pike and Godfrey (2014) described a compliance model consisting of two groups: one was "core labor standards," which mainly focused on factors such as child labor, forced labor, and discrimination. The second was "working conditions," which mainly focused on factors such as OHS, ergonomics, compensation, and working time. This thesis mainly focuses on OHS and ergonomics, which belong to the second group. OHS and ergonomics in garments have been studied, and there are many factors that contribute to health and safety in the workplace. Another critical challenge is the ergonomics condition, which is allied with inappropriate workstation design. The RMG industry is known to entail repetitive tasks such as sewing, and it carries a high risk of repetitive strain injuries (RSI) for the operators (Ozturk & Esin, 2011; Sealetsa & Thatcher, 2011). Additionally, the lack of proper ergonomic consciousness of RMG manufacturers causes a high risk of musculoskeletal disorder (MSD) for workers. Because of the inadequate design of work stations in the RMG industry, operators are exposed to various strains (Van, Chaiear, Sumananont, & Kannarath, 2016). For example, sitting with a curved upper back and the head directed toward a sewing machine results in bad posture of the neck and back. The poor working conditions in the RMG industry have generated MSD in workers and consequently an increase in various illnesses, causing many concerns for businesses (Melo Junior, 2012).

Since its foundation, the garments industry of Bangladesh has achieved tremendous feats, but numerous things remain to be achieved to reach its peak. The garments industry is susceptible to various types of challenges, which are currently hampering the growth of the RMG industry. However, it is not easy to overcome external challenges. In addition to the unfeasible challenges, there are several internal challenges for factories, such as compliance issues, productivity, and lead time which can be solved with the help of new production and management philosophies, such as lean tools with the integration of OHS. The application of lean and OHS integration is a relatively new concept in the RMG sector. This thesis focuses on the integration of lean tools and OHS to improve the productivity of garment factories in Bangladesh, as well as overcome the factory-level or internal challenges in the country's RMG industry.

2.2. LEAN IN THE GARMENT INDUSTRY

As discussed in the previous section, the RMG industry of Bangladesh is tainted by both external and internal challenges. To overcome the factory-level or internal challenges such as productivity and OHS, different types of production techniques must be implemented. In modern working life, it is common to find working systems in search of high efficiency (Westgaard & Winkel, 2011), along with providing good quality products according to customer demands at a low production cost to survive in today’s competitive global market (Gollan, 2005). One of the effective manufacturing philosophies is “Lean.” Various manufacturers in the RMG industry are adopting lean to enhance the quality of their apparel products with low cost and shorter lead times to achieve competitiveness over others (S. K. P. N. Silva, 2012). Lean has also been introduced in garments in developed countries; for instance, in a study in the US, garment manufacturers perceived the importance of improving their productivity to compete with manufacturers in overseas countries (Hodge, Goforth Ross, Joines, & Thoney, 2011). Through applying lean philosophy in the garment sector, it is possible to reduce the overall costs of the industry by reducing various types of waste from the production system, along with the tendency to fulfill customer demands over the quality of products and on-time delivery (Farhana Ferdousi, 2009). Various countries have started to implement certain lean tools with the intention of capturing the global competitive market, and they have observed positive results in the RMG sector. However, the long-term sustainability of lean tools in the RMG industry remains vague—this is because factories do not properly consider OHS and, in most cases, it is only the initial phase.

2.2.1. THE LEAN CONCEPT

Lean philosophy originated in Japan from the Toyota Production System (TPS) (Bowen, Spear, & Bowen, 1999; Ohno, 1988). However, Johan Krafcik (1988) first used the term “*lean production,”* and lean received worldwide attention when Womack, Jones, and Roos (1990) published the book *The Machine That Changed the World*. In spite of severe challenges during the oil crisis of 1973, Toyota’s performance was remarkable. This encouraged MIT to launch the ‘International Motor Vehicle Program’ (IMVP), to understand the challenges facing the automobile industries at that time and map the lean production system (Arezes, Dinis-Carvalho, & Alves, 2015). Lean has been popularized because of its effective management methods for improving efficiency and performance of an organization (Moyano-Fuentes & Sacristán-Díaz, 2012). Over the years, the lean concept has been improved by scholars and practitioners through accommodating good practices of TPS (Jasti & Kodali, 2019) and gradually extending its practices across sectors. The main concept of the lean production system is to eliminate waste throughout the overall value chain and improve continuously. Waste in manufacturing includes over or under production, excessive movement of materials and people, unnecessary processes, and defects, as well as processes that do not directly add value to the product (Womack et al., 1990).

To date, no well-known explanation of lean adoption exists. Its implementation varies in process as well as context (Håkansson, 2019; Hasle et al., 2012), which is similar to the description of Kaur et. al. (2016). Lean uses different tools to reduce the waste, and studies have suggested that these tools are sometimes used independently or as a bundle where a set of tools is selected based on the context and nature of the intervention (Mostafa, Dumrak, & Soltan, 2013; Pearce & Pons, 2013). Scholars found that the effect of practicing lean tool bundling is greater than that of individual tools (Shah & Ward, 2003). In the selection of both individual and bundled lean tools, it is very difficult to distinguish which tools are most suitable in which condition. Additionally, the application of lean tools depends on techniques, skills, experience, and lean guides or consultants (Kaur et al., 2016). Other studies have suggested that the adoption of lean tools also depends on the product variety and product volume (Esfandyari, Osman, Tahriri, & Riedel, 2007; Fawaz A, Rajgopal, & Needy, 2006).

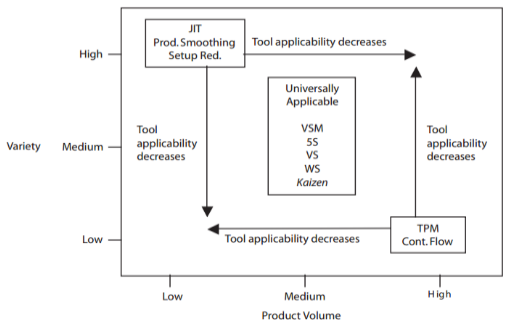

Figure 1: General guidelines for applying lean tools in the process industry (Fawaz A et al., 2006).

Figure 1 is simplistic guideline for the implementation of lean tools depending on the industry type. From the figure, it can be determined that under high-volume and high-variety conditions, the system tends to show the applicability of the tools Just in Time (JIT) and Total Product Maintenance (TPM) decreases, whereas the other lean tools remain universally applicable throughout the systems (Fawaz A et al., 2006).

2.2.2. LEAN TOOLS' EFFECTS ON RMG

A significant potential exists for increasing the competitiveness of the RMG industry by improving its productivity with the help of lean production techniques. Several factory owners have taken the initiative to implement lean tools on a pilot basis, and various researchers have also started to study this sector. Most of these independent cases have obtained positive results on productivity. Table 1 presents a summary of lean tool applications in the RMG sector.

Table 1: Lean tool applications in the RMG sector.

Parameter	Tools	Results/Results on productivity	References
Production time	Kaizen event, TPM, 5S, Single-Minute Exchange of Die (SMED), and a bundle of lean tools (literature not specified)	Cycle time reduced by 34%	(Marudhamuthu, krishnaswamy, & Pillai, 2011; Vijayakumar & Robinson, 2016; Dharmasri Wickramasinghe & Wickramasinghe, 2011; G. L. D. Wickramasinghe & Perera, 2016; G. Wickramasinghe & Wickramasinghe, 2017)
		Cut to Ship Ratio increased in the range 10% to 35%	
		Dock to dock time reduced in the range 43 to 20 days	
		On-time delivery time increased in the range 4% to 30%	
		Production Lead Time reduced by 6.8 hr	
		Setup time reduced by 20 min	
Efficiency	5S, TPM, JIT, VSM, TQM, Visual management, Kanban	Efficiency increased in the range 12.5% to 90%	(Carvalho, Carvalho, & Silva, 2019; Marudhamuthu et al., 2011; Quddus & Nazmul Ahsan, 2014)
Quality	5S, Defect per Hundred Units (DHU), Kaizen event, Cause and effect diagram	Defective garments reduced by 6.02%	(Ahmed, Islam, & Kibria, 2018; Quddus & Nazmul Ahsan, 2014; Vijayakumar & Robinson, 2016; Dharmasri Wickramasinghe & Wickramasinghe, 2011; G. Wickramasinghe &
		Rework reduced by 75%	
		Defect rate reduced by 6%	
		AQL increased by 8%	

			Wickramasinghe, 2017)
Waste	VSM, 5S, SMED, Kanban	Work in process reduced in the range 30-90%	(B. S. Kumar & Sampath, 2012; D. V. Kumar et al., 2019; Quddus & Nazmul Ahsan, 2014; S. K. P. N. Silva, 2012)
		Value added increased in the range 105% to 152%	
House keeping	5S, VSM, 6S	54.67m^2 floor space saved	(Ahmed et al., 2018; Quddus & Nazmul Ahsan, 2014; Vijayakumar & Robinson, 2016)
		Cleanliness score increased 78%	

amet However, much of the evidence in the literature addressed in Table 1 is of quite a low quality. In addition, evidence from the literature (see Table 1) indicates that lean philosophy is a comparatively recent approach in garment manufacturing industries. In the table, results of some lean tools that have been applied in the RMG sector are presented. However, as these tools were used in bundles and the results were measured cumulatively, it is difficult to perceive the influences of the individual tools on productivity. Thus far, several different tools have provided reasonably good evidence in terms of productivity, although in most applications the tools have been used for an experimental state, pilot line, or initial implementation phase. However, it is reasonably safe to conclude that many lean tools will show positive effects on productivity in the RMG sector.

Suggestions from the literature in Table 1 generally indicate which tools are fit to apply in the RMG sector. Moreover, other researchers have provided guidelines on which lean tools to use for high product volume and high product variety processes, such as in the garments sector. One author suggested that garments (“tailoring” was used in place of “garment”) are high-volume and high-variety types of product (see Figure 2) (Esfandyari et al., 2007). In addition, Fawaz A et al. (2006) described the general guidelines for lean tool application in high-product-volume and high-product-variety processes (see Figure 1). The same authors also explained that in such processes in the RMG industry, JIT and TPM are not valid.

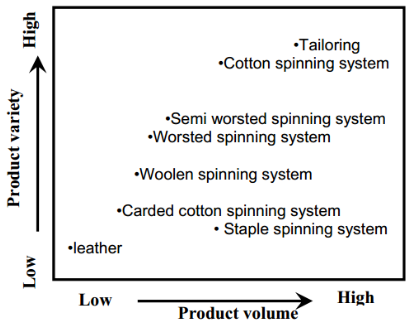

Figure 2: General classification of textile production systems based on material variety and product volume (Esfandyari et al., 2007).

However, these two articles were published 12–13 years ago. Furthermore, with the ever-changing fashion trends over these years, the current effects of JIT and TPM in the RMG sector would not be similar as previously thought. Today, the planning efforts on the production floor are much more important for the manufacturer to deliver the product on time to the buyers. This is because of the increasing requirement of shorter product delivery times. A delay in the delivery of a product might cause the product to become obsolete. Along with this, the increasing trend of the online marketplace demands shorter delivery times, which puts more pressure on distribution centers. Furthermore, JIT helps manufacturing facilities to ensure the delivery of products to the buyer at the assigned time. In addition, the JIT technique is used in the form of the Kanban concept with the integration of VSM on sewing production floors (Nunesca & Amorado, 2015). Because of this, the need to use JIT on the production floor and in the supply chain has been increasing.

Another tool, TPM, is mainly used to address frequent failure of equipment (Ahuja & Khamba, 2007). TPM is a useful tool for machine maintenance and widely used complementarily with other manufacturing tools such as TQM, JIT, and total employee involvement (D Wickramasinghe & Wickramasinghe, 2012). However, Fawaz A et al. (2006) and Esfandyari et al. (2007) have suggested that TPM is less valid in the RMG industry. However, to understand the relationship between TPM and the operational performance of the RMG industry, very limited literature has been found. TPM has higher priorities in continuous production, which requires complex machinery. In cases such as an automobile assembly line, if any hindrance occurs in the production process, then the whole process is stopped—this makes the use of TPM essential. In the case of the RMG sector, central maintenance teams are responsible for all equipment maintenance, and their approach is to respond only when a problem arises (G. L. D. Wickramasinghe & Perera, 2016). The tendency of garment manufacturers in Bangladesh is to try to resolve replacing a troubled sewing machine only when it causes disturbances or hindrances. This approach is not appropriate in the modern competitive global RMG market because of shorter lead times, quality and safety. Therefore, today, TPM is also given priority with other lean tools for machine maintenance to improve the machine efficiency and quality of products in the garment industry.

To sum up, according to the literature and aforementioned discussion, the various lean tools that are suitable in the RMG industry and their effects are discussed in Table 2 below.

Table 2: Suitable lean tools in the RMG industry.

Lean tools	Effects
VSM	Less inventory and work in process (WIP), reduced worker fatigue
Time and motion study	Operation with the right method, efficiency
5S	Cleanliness, workstation redesign, improved worker movement
SMED	Decreased setup time
Kaizen	Improved efficiency, teamwork, and commitment of workers, and increased participation
DHU	Reduced defects, improved product quality
TPM	Cost effectiveness, increased product quality, timely delivery, and increased flexibility volume
Kanban	Less inventory and WIP, improved worker movement

My suggestion is that the tools listed in Table 2 should receive priority for being applied in the RMG sector. Thus, the next question is how to implement them. They are not easy to implement, especially in the RMG sector (Haque, Chakrabortty, Hossain, Mondal, & Islam, 2012). Many challenges exist in the application of lean tools, and these are presented in the next section.

2.2.3. CHALLENGES IN LEAN TOOL APPLICATION

Despite several attempts at applying lean tools, most factories are still not achieving the proper benefits of the lean program (Lucey, Bateman, & Hines, 2005). Various studies have indicated that two out of three attempts at lean application in companies result in failure (Aiken & Keller, 2009; Beer & Nohria, 2000; Hopp, 2018). Anvari et al. (2011) and Flinchbaugh (1998) have emphasized not only the higher rate of failure during lean application but also several kinds of challenges that arise during it. One of the major challenges was identified by Jagdish and colleagues (2014), which is the resistance from top management and mid-level managers. This is due to their reluctance to change and adopt something new, a fair amount of uncertainty, and a lack of clarity (Spencer, 2008). Even if the top management is convinced, the next challenge is the lack of consultants and trainers to successfully implement lean and continue it to achieve benefits (Jadhav et al., 2014). Moreover, in developing countries, it is difficult to engage workers in something new because of the lack of a learning culture, which also hampers the long-term success (Bowen et al., 1999; Imai, 2012; Liker, 2004).

Compared with in developed countries, these challenges are much more amplified in developing countries. This is because of factors such as the learning paradox, high worker turnover rate, lack of worker involvement and participation, and lack of implementation processes (Maalouf, Hasle, Vang, & Hoque, 2019). According to the philosophy of the learning paradox, to learn about something, one must first know that thing (Maalouf & Gammelgaard, 2016). In developing countries, RMG workers do not have any idea about the term “lean,” let alone the benefits of it, which due to the learning paradox does not encourage them to learn about it.

Most shop floor workers in developing countries are uneducated and unskilled, and to transform these unskilled workers, companies must arrange training programs related to lean manufacturing. However, after receiving such training, the now-skilled workers show a tendency to migrate to other manufacturing factories, which is another challenge for lean implementation in the garment industry.

Another reason identified is the lack of communication between top management and workers (Kgdas, Wpgt, Lpcb, Hsc, & Jr, 2018). Training of workers is mainly classroom-based (N. Silva, Perera, & Samarasinghe, 2011), which makes it difficult for the workers to implement lean in the production line. In addition, similar to previous findings, Malek and colleagues (2019) highlighted in their research that a lack of commitment from workers and reluctance to learn are hampering the process of implementing lean tools as well as their sustainability in factories. Therefore, during lean application, these factors must be considered carefully.

Therefore, my conclusion is that lean manufacturing has benefits for productivity, but still has several challenges in its implementation. In addition to still being debated, lean has consequences for workers' health and safety, as well as influences how they do their work. Studies have also shown that health and safety has an indirect relationship with productivity. Enhanced working conditions optimize interactions between work and the workers, thereby eliminating potentially serious hazards and disabling work-related injuries. These are the issues related to OHS that are indirectly related to productivity. In the next section, I discuss working conditions in terms of OHS and ergonomics in the RMG sector, as well as a possible integration of lean, OHS, and ergonomics.

2.3. OHS AND ERGONOMICS IN THE GARMENT SECTOR

In the previous sections of this chapter, I discussed the challenges the RMG industry faces in Bangladesh. Subsequently, I discussed the application of lean tools as a possible solution to the internal challenges in this sector. However, the effects of lean-tool application have ambiguous results when it comes to evaluations of workers' health conditions (Hasle, 2014). Therefore, this section presents a general overview of OHS and ergonomics as well as their effects on employee health in the RMG industry.

2.3.1. OCCUPATIONAL HEALTH AND SAFETY (OHS)

Before this section discusses the literature on the benefits of OHS for productivity, it elaborates on the definition of OHS. According to ILO/WHO, OHS is defined as "*the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations*" *(ILO, 2003, p. 7)*. In detail, OHS can be described as a complete method of identifying workplace hazards, assessing them, and controlling them so that the health and wellbeing of the workers are safe. OHS also considers the work environment and surrounding communities to ensure a congenial physical, mental, and social atmosphere for the workers. It is also true that the right to work safety is universal, and it is the fundamental right of employees (ILO, 2009). For workers to gain these rights, active organizational support is required; Ellen et.al. (2016) emphasized not only individual and organizational culture but also social and economic conditions and legal and political situations.

OHS has a long history of being subject to both government regulations and company efforts to manage risks. For many decades, research on health and safety aspects at work has been extensive. In the traditional manufacturing industry, knowledge about risks, their effects on health, and the possibilities for prevention are in most cases well-established—the main problem is that the knowledge is not applied in practice. As manufacturers are focusing more on efficiency and productivity to survive in the global competitive market, they have a tendency to neglect the implementation of OHS in the industry (Lund & Marriott, 2011; Sant'Ana & Kovalechen, 2012).

The possible reasons for this are knowledge gaps, OHS implementation costs, and business strategies that do not consider OHS as a key element of success. However, studies have shown that safety improvements can also improve operation performance and business success (Lee, 2018; Sultan-Taïeb et al., 2017). Obtaining greater operational performance requires occupational risk to be reduced, which helps to create enhanced working conditions. The four main categories of occupational risk factor are physical, chemical, ergonomic, and biological (Sparks, Faragher, & Cooper, 2001). The outcomes of each risk factor on OHS performance have been extensively described in the literature (Mousavi, 2017). Of all four-risk factors, physical and ergonomic risks are the most related to the RMG sewing floor.

Thus, in this thesis, I use OHS as a general concept for workplace risk, control of risk, and in particular the relationship between workers and the workplace. The word “ergonomics” is used to describe making workers and the workplace have the best possible fit.

2.3.2. ERGONOMICS

In this thesis, I use the definition of ergonomics provided by the International Ergonomics Association (IEA), which is as follows:

“Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system performance.”(IEA, 2010)

Therefore, we can say that ergonomics is the science of optimizing the interaction between work and worker. Furthermore, in the context of the RMG industry, it should involve reducing various potentially serious and disabling work-related MSD, which is indirectly related to productivity. Although the concept of ergonomics is relatively young, it is aligned with the risk and deterrence of risk of the traditional OHS concept. It helps to evaluate the current ergonomic conditions of the workplace, which helps to improve OHS conditions as well as the productivity of any factory (Maia, Alves, Leão, Leao, & Leão, 2012). Moreover, ergonomics focus on the integration of human and production technology in a manner that mutually results in creating a healthy environment and effective production (Lehto, 2018). In this way, ergonomics connect OHS and productivity (W P Neumann & Dul, 2010). As long as OHS in the RMG sector is concerned with work postures, then lifting, carrying, and repetitive work are the important risk factors that can lead to MSD. In addition, ILO identified seven potential risk factors (ILO, 2010), which are included in the present study and listed as follows:

- Workstation design
- Materials handling
- Layout and housekeeping
- Repetitive work
- Accident risks
- Lighting
- Temperature

My study concentrates on these seven factors because they are possibly the most common OHS and ergonomic risks in the RMG industry. For example, because of improper workstation design, material handling becomes difficult for workers. In many factories, the machines can be observed to be placed too closely together to save space, which results in problems in material handling as well as housekeeping. MSD and fatigue are caused by bad postures and incorrect movements of workers are caused by inappropriate workstation design. Moreover, because garment sewing is repetitive work, the possibility of accidents increases if the abovementioned factors are not in the right order. Furthermore, lighting is another problem that can cause eye diseases in workers if the lumen prescribed according to ILO is not maintained. Moreover, improper temperatures cause workers to sweat more and get sick, which also hamper their productivity. Thus, all of these seven factors have effects on productivity as well as working conditions in the garments industry if they are not designed and maintained properly. Accordingly, from the above discussion, it can be said that ergonomics ensures optimum conditions between workers and their workplace. This also has a relationship with lean, because lean also deals with how to fit the workplace and workers in a more efficient manner.

To sum up, the above discussion about ergonomics indicated that the seven aforementioned factors are crucial for workers' health as well as productivity. In the next section, I provide an overview of OHS and ergonomics in the RMG sector.

2.3.3. EFFECTS OF OHS AND ERGONOMICS IN THE GARMENTS INDUSTRY

Studies have shown that the working population of the garment sector bears a significant percentage of the global victims of occupational disease and injury (Melo Junior, 2012). The workplace conditions for garment workers make them quite vulnerable and have been followed by the rapid increase of garment factories (Sant'Ana & Kovalechen, 2012). Large problems exist with OHS in developing countries such as Bangladesh. Common OHS problems include working conditions, worker health, poor buildings with insufficient ventilation, overcrowded factories, and improper storage of flammable and dangerous materials creating serious hazards. All of these happen because of the absence of adequate safety standards in the industry (Akram, 2015). For instance, the Rana Plaza and Tazreen Fashion tragedies have exposed the vulnerabilities in workplace safety, and the RMG sector has been receiving pressure from all corners for workplace improvements.

More specifically, the problems in the garment industry are caused by the repetitive nature of the work (sewing operations), for which there is a high chance of workers developing health problems such as MSD, which a long series of studies have confirmed (Herbert et al., 2001; Jahan et al., 2015; Melo Junior, 2012). Additionally, substandard working conditions or work stations with poor ergonomics cause problems such as MSD, mental stress, and other biomechanical factors during work (Van et al., 2016; Yu et al., 2012). Garment workers are provided with workstations that do not abide by the ergonomic design principle, resulting in poor worker postures and inadequate seating, leading to MSD (Channa, 2008; Dillard & Schwager, 1997; M. I. Ali, M. S. Rahman, M.S. Parvez, 2014).

For this thesis, I focused on OHS and ergonomic perspectives such as redesigning workstations, workflow, housekeeping, and material handling from workstation to workstation for successful improvements in productivity and worker health in the RMG industry. For productivity concerns, I considered lean tool applications, which were discussed in previous section. Because lean has mixed (positive and negative) results on workers' wellbeing (i.e., OHS), one possible solution may be integration between lean and OHS. In the next section, I provide an overview of lean and OHS integration for the workplace for enhanced productivity, especially on the production floor.

2.4. POSSIBLE SYNERGIES BETWEEN PRODUCTIVITY OHS, AND ERGONOMICS

The shift from conventional to lean production systems requires workstations to be redesigned and worker activities to be changed, which can both effect OHS. However, the relationship between productivity and OHS has only been studied to a limited extent in the literature, and not at all in the RMG industry. Therefore, I searched for general literature contributions about the possibility of synergies.

Several researchers have investigated the opportunities of a synergy between productivity, OHS, and ergonomics for decades. For instance, OHS helps to make workplaces safer and healthier, which results in a productive workforce, improved financial performance, and lower healthcare costs (K. A. Brown, 1996; Fernández-Muñiz et al., 2007; Gahan, Sievewright, & Evans, 2014; Hoffmann, Rudra, Toor, Holm-Nielsen, & Rosendahl, 2013; Longoni, Pagell, Johnston, & Veltri, 2013). This is similar to the findings of Walton (1985), who emphasized how workplace safety influenced better human resources management (HRM). If workers are not satisfied with their working conditions, it could be difficult to manage better HRM, which would result in a high level of employee turnover and absenteeism (Locke & Romis, 2007), the resignation of employees (Peterson, 2009), a decrease in mental health, and low levels of cooperation. All these contribute to reduced productivity. By contrast, job satisfaction results in positive behavior, increased motivation, a more productive worker base, and greater benefits for the company.

Turning to lean and OHS, the first studies pointed almost entirely toward negative consequences; however, during the last decade, researchers investigated the opportunities of a synergy between both lean and ergonomic practices (Saurin & Ferreira, 2009). Recent research has shown a stronger complementariness between lean and OHS, which is different to the antagonistic outcomes in the past. Lean has an influence on workers in how they do their work. This is why it is important to see the relationship of lean with productivity and OHS. Again, the ergonomics factor must be considered to properly link lean with OHS to ensure better worker health and productivity. Ergonomics research is also searching for a relationship between lean and ergonomics; for instance, by developing new VSM tools that integrate ergonomics. For a better understanding of working environments, Ergo VSM is a distinctive tool that focuses on the evaluation of ergonomics in the traditional VSM tool for validation, which emphasized the reduction of waste (Jarebrant et al., 2006). The application of Ergo VSM reduces the duration of manual working time as well as reduces individual risk factors. In more detail, ergonomics practice involves designing workstations with attention to human capabilities to reduce fatigue and injury (Pai, 2010), with the view to providing additional utensils for creating value as well as improved quality and performance within the organization (Hall-Andersen & Broberg, 2014; Kester, 2013; Pai, 2010). It is gradually becoming important in the industry to a greater extent because of its positive influence on productivity and efficiency as well as its focus on reducing occupational injuries (Gibson & Mrugalska, 2019).

However, for some reason, workers have negative effects on lean implementation because OHS is not properly addressed or ergonomic considerations are isolated from the workplace. Literature provides some evidence; for example, Brown and his colleague (2007) investigated the effects of lean on worker health and safety in Chinese industry, and the results turned out to be negative. They performed a case study with an empirical study following the implementation of the lean approach. Finally, occupational hazards were significantly increased, which indicated the negative impact of lean production on OHS. Other researchers have also indicated that lean companies have reported fatigue and job stress in employees, leading to them experiencing MSD, absenteeism, turnover, and complications in performing work tasks, such as fatigue (Conti et al., 2006; Hasle, 2014; Pai, 2010). These findings were also supported by Hasle et al. (2012), who performed a literature review regarding lean and the working environment for different industries. The review indicated some significant adverse effects on workers' health in lean environments, such as fatigue and stress anxiety. Fatigue in workers affects their performance, which consequently increases time delay, damages product quality, and thus produces waste (Eswaramoorthi, John, Rajagopal, Prasad, & Mohanram, 2010), ultimately affecting productivity. In recent years, several researchers have presented numerous descriptive models for integrating lean and OHS. For instance, Hasle et al. (2012) explained in their model that the association among lean and working environments not only concerns the lean implementation strategy but also the industrial context. This argument was also supported by another study where the effect of lean practice on safety climate (Longoni et al., 2013) was described.

Thus, the effect of lean on productivity, OHS, and ergonomics has not been studied before, especially in the RMG industry. This is the main research gap addressed in this thesis. Some possibilities exist for synergies, which has been mentioned in the general literature. Looking into the garments industry, it is still an open field for research in terms of whether such synergy is applicable here. However, because lean creates large interferences in garments in terms of workstation design and material handling—which are also related to ergonomics—it can be said that a strong possibility exists for the synergy to exist. Studies on RMG have indicated positive effects of lean on OHS. Chapter 4 will return to discuss this in detail.

Taken together, developing countries such as Bangladesh are facing internal and external challenges. To mitigate the internal challenges, such as productivity and compliance, lean is a tool that could offer improvements in productivity. Some indications are relatively clear that lean can benefit productivity, but the implementation process is not clear. Moreover, some research have indicated the tools most likely to be relevant to the RMG sector. However, lean has some negative indications in terms of worker health, which can be a problem, but most studies have indicated that lean can be beneficial. Based on the literature review, I applied some of the lean tools with OHS and ergonomics integrated to secure better working conditions and productivity, and I simultaneously identified synergy between them. The next chapter draws an outline of the research design and clarifies how the integration between lean, productivity and OHS was realized.

CHAPTER 3. METHODOLOGY

3.1. APPROACH

This thesis studied the possibilities of improving productivity with the integration of OHS. This chapter covers the chief research strategies and study framework that were used in this thesis. This research is the part of the POHS project and is based on action research. Action research is based on the idea of acquiring new knowledge by introducing change in real-life situations (Greenwood J. & Levin, 2007; Nielsen & Svensson, 2006). Action research has a long custom in both operations management (Bamford, Forrester, Dehe, & Leese, 2015; LaGanga, 2011) and OHS management (Hasle & Jensen, 2006; W Patrick Neumann, Ekman, & Winkel, 2009). Action research is built on a program theory (Bickmann, 1987) about the effects of certain changes. In this project, I analyzed the real scenario prevailing in RMG factories to integrate productivity and OHS during lean implementation. For that, I designed a research strategy to collect information from the actual stakeholders working in the target industry environment. This action research required the skills to implement lean tools and facilitate the industry to work on productivity and OHS improvements. I measure the outcomes for further analysis and provide the discussion in later parts of this thesis.

This study developed knowledge about the possibilities of improving productivity with OHS integration in garment factories with the use of lean tools. This thesis is based on the outcomes of an intervention applying lean tools with OHS integration in RMG factories in Bangladesh. The intervention was planned in collaboration with case companies and data regarding the intervention research, which were collected before and after the intervention. The analytical approach followed the Context, Intervention, Mechanisms, and Outcomes (CIMO) model, which was suggested by Aken and colleagues (2016) for operations management research. CIMO is built on a design science approach (Kaipia, Holmström, Småros, & Rajala, 2017) and used to facilitate a comparison of differences in context and intervention practices, thereby identifying the mechanisms that can increase the possibility of successful interventions. Using the CIMO model, the goal of this study was to provide valid guidance for the garment sector in Bangladesh and other developing countries on the future application of lean with the integration of OHS.

In an earlier section, I stated that this thesis is part of the POHS-BD project; accordingly, in my Ph.D study, I had access to all the data collected for the POHS project. Therefore, I now provide a short description of the POHS project methodology and later my Ph.D's part within this framework.

3.2. OVERVIEW OF THE POHS PROJECT METHODOLOGY

The main objectives of the POHS project are to generate knowledge about sustainable co development between productivity and OHS and to improve productivity with the integration of OHS practices in RMG factories in Bangladesh. This research project employed a mixed-methods design, where combinations of quantitative and qualitative data over multiphases were used. The design was a mixed-methods study originating from the twofold nature of the research object: creating an overview of the generic problems that occur in multiple organizations and increasing understanding of actual learning in the implementation processes in their natural setting, such that the results of the research could be easily applied in practice. In addition, the benefit of the mixed-methods approach is that bias is reduced (Curran, 2008). This research project included three stages: a baseline study, an intervention, and a sustainability follow-up. A description of each section is given in the following three subsections.

3.2.1. BASELINE STUDY

The main objective of the baseline study was to acquire knowledge regarding the current productivity and OHS maturity levels of RMG firms in Bangladesh. The capability maturity for productivity was based on lean literature and continuous improvement maturity assessments (Bessant & Caffyn, 1997; Melenovsky & Sinur, 2006; Womack et al., 1990) as well as Gartner's capability model (Kerremans, 2008), which included both technical and organizational dimensions with special attention to institutionalizing practices. The model consisted of five levels starting from ad-hoc application, which allows the current maturity level to be identified and the actions to move forward to the next level to be perceived. This model is also integrated with OHS through Fleming's safety maturity model (Fleming, 2001), which identified corresponding safety maturity levels. The baseline study included identifying practices and outcomes (i.e., key performance indicators; KPIs) in respect to the technological level (e.g., machine set-up), reliance of operation management methods (e.g., lean), productivity level (e.g., input/output measures), and Fleming's OHS measures (e.g., management commitment, safety resources, and trust). Using the two models, data were collected from 50 garments factories in Bangladesh. Subsequently, the research team arranged a meeting, which included giving feedback to the management.

3.2.2. INTERVENTION

After finishing the baseline data collection, the next step was to intervene in 12 companies. The objective was to achieve sustainable and mutual supportive OHS and productivity improvements while developing and testing possibilities for the practical application of lean tools. The intervention was organized in two waves: wave 1 and wave 2. Each wave intervention was conducted in six factories and the time range for each intervention was 8–10 months. Every intervention was divided into four stages:

(1) the introductory phase; (2) baseline data collection; (3) intervention; and (4) post-measurements.

The intervention started with identifying possibilities for improvements in collaboration between the researchers and management. The actual change process was tailored to each factory depending on needs and priorities and implemented by the factories' operational teams supported by the researchers. All factories worked with improvements related to VSM, time and motion study, 5S, SMED, lean flow and workstation redesign to identify possibilities for improvements, including both productivity and OHS improvements. The intervention process was completed through measurements of effects, which included measurements of the same KPIs after the intervention.

3.2.3. SUSTAINABILITY FOLLOW-UP STUDY

This activity focused on the sustainability of the previous activities that implemented the designed and tailored interventions. Six months after the intervention process was completed, the sustainability outcomes were evaluated. The intervention would be considered sustainable if the practices were still performed in that time while simultaneously improving the KPIs.

In the next section, I give an overview of my Ph.D study area within this framework.

3.3. RESEARCH DESIGN FOR PHD STUDIES

For this thesis, I focused on the application of lean tools in garment production floors, the physical and psychosocial working conditions, and in turn, employees' health.

Thus, the first study was based on a baseline study where OHS and productivity maturity level assessments of 50 baseline factories were conducted. The second study performed a literature review within research themes about lean, OHS, productivity, and the RMG industry (Hamja et al., 2019b). Next, the third study was on the assessment of productivity data, physical workload or fatigue, and musculoskeletal pain in a lean intervention plant, which was executed and analyzed in collaboration with factory personnel. In addition, the combination of researcher observations and worker interviews were used for data collection regarding musculoskeletal pain. Finally, using CIMO logic in a developing country especially in the RMG sector, the successful lean implementation mechanisms was identified and explained in the fourth study. For more details, an overview of the research design in each study is presented in Table 3.

The included companies' lean practices were apprehended through interviews with the management, productivity data measurement, middle management, floor level workers, planned visits to the production site, KPIs, and document studies. This triangulation was performed to obtain diverse perspectives on the work content for the employee, as well as to obtain both an employee and management perspective on what they had done in their lean work and what the employees' participation had been in continuous improvement. In the project, all collected data in the logbook was maintained methodically.

Table 3: Overview of the objectives, focus, research design, data, and type of analysis in each study.

Study and RQ	Objective	Focus	Design; Data	Analysis
1. Are productivity and OHS contradictory or complementary in the garments industry?	To document current management of OHS and the level of productivity in the industry.	The garment industry of Bangladesh in two different regions—Dhaka and Chittagong.	Questionnaires; Interviews with production managers and compliance managers and 5 Scale assessment of OHS and productivity practices	**Quantitative**: Pearson coefficient **Qualitative:** Descriptive content analysis
2. What is the relationship between lean tools and effects on productivity and OHS in the RMG sector?	To review empirical and descriptive studies regarding lean on occupational health and safety and productivity in the garment industry.	The garment production process where lean manufacturing is used and possible consequences for OHS and productivity.	Literature review	Summary of results, methodology, lean practice, OHS practice, and outcomes.

3. What are the effects of lean application on workers' health in the garment industry?	To assess how lean contributes to occupational health and safety in the RMG industry.	Six Bangladeshi garment factories.	Worker questionnaires about different body regions; Production data	**Qualitative:** Assessment of OHS consequences for lean implementation in the production line. **Quantitative:** Pair-wise comparison (*t*-test); efficiency; 5S Score; percentage of value addition
4. What are the transfer mechanisms for successful lean implementation in the RMG sector?	To understand what mechanisms and actions promote sustainable lean transformation in RMG.	Four Bangladeshi garments factories using CIMO logic.	Two-wave production data, employee questionnaires, interviews with managers	**Qualitative:** Productivity and OHS KPI **Qualitative:** Possible mechanism for successful lean application

3.4. SELECTION OF SAMPLE

For the baseline study, the snowball sampling technique was used to select 50 garment factories in the initial part of the POHS-BD project (Biernacki & Waldorf, 1981). The criteria for selecting the factories were to ensure all were BGMEA-listed, all were 100% export-oriented, and all were located in Dhaka or Chittagong, the two central garment-industry areas of the country. It was ensured that the factories varied in plant size. This is because the availability of resources and intensity of institutional pressure varies with different plant sizes; plants were identified as small, medium, or large according to their number of employees (see Table 4).

Table 4: Plant size and employee numbers.

Size	Employee range	Total number of factories
Large	More than 2000	23
Medium	Range between 500–2000	19
Small	less than 500	8
Total		50

Later, based on the involvement of the factory and our capacity, 12 factories were finally selected for two wave intervention stages. To ensure the factory involvement, top management commitment was key in some factories, and in the other factories interest grew because of pressure from the buyers' side. All the 12 factories were export-oriented, basic RMG sewing factories. Agreement was made to allocate one production line in each factory for the lean implementation. All the factories were producing similar types of end products to ensure consistency of the results.

These 12 factories were divided between three Ph.D fellows according to their project design. However, each PhD fellow had access to all factories and could collect data according to their needs. In Study III, I included six factories from the second wave where I had an elaborate intervention and there had the best possibilities to show differences between before and after. In the last study (Study IV) I used two cases from the first wave and two cases from the second wave where I had the responsibility to handle the intervention, and thus had the possibility of going in depth in the study of mechanisms. In Table 5, I present the factories I included in my whole PhD study.

Table 5: Intervention factories' list and those that were included in the study.

Factory	Wave 1	Wave 2	Study No.
F-1	X		4
F-2	X		4
F-3		X	3 and 4
F-4		X	3 and 4

F-5	X		
F-6		X	
F-7		X	3
F-8		X	3
F-9	X		
F-10	X		
F-11		X	3
F-12		X	3

3.5. DATA COLLECTION

The whole data collection was divided into two stages, the first was baseline data collection (study I) and the second was the intervention stage (study III and IV). For this thesis, data were collected between 2015 and 2019. Data from several different sources were included; that is, a literature review, production data, questionnaires for workers and managers with a focus on lean manufacturing, OHS, and ergonomics, data for pain intensity in sewing-line workers, and mechanisms for successful lean implementation.

3.5.1. DATA COLLECTION IN THE BASELINE STUDY (STUDY I)

The baseline study focused on gaining knowledge regarding the present maturity level of productivity and OHS of the RMG industry. For the determination of maturity levels, 11 dimensions were considered for OHS management and operational improvement individually. The scoring characteristics were five-step progression levels, where scores of 1 to 5 were given for each practice, and the results were determined by averaging the individual ordinary scores of the 11 practices. Data for the 50 garment factories were collected over 1 year (June 2015 to June 2016) by the POHS project. For data in this study, three groups of researchers formed of PhD students, research assistants, and professors from AAU and AUST were involved in two or three visits to each company. The first visit was an introductory visit or phone call for basic information collection and an overview of the production setup. The main data collection was performed on the second or third visit (if the data were not collected completely already), which was done as soon as possible after the first meeting with the aim of obtaining the required information from the company and differentiating the data sources for scoring. In addition, three types of data interview (semi structured interviews with managers for OHS and productivity maturity level), documentation (minutes of meetings, production datasheets, training material, policy and norms, etc.), and observations (shop floor conditions such as layout, housekeeping, and safety signs) were collected from the factories.

3.5.2. DATA COLLECTION FOR THE REVIEW ARTICLE (STUDY II)

In Study II, a literature review between 1990 and 2019 was conducted, where I focused mainly on the relationships between the implementation of lean, OHS, and productivity outcomes of the RMG industry. This was done by identifying and analyzing the relevant studies with a standard literature search procedure known as the systematic literature search approach (Grant & Booth, 2009). The existing literature was analyzed to search for studies where qualitative, quantitative, as well as mixed-methods were used in peer-reviewed international journals. The journal papers were screened from selected databases such as Business Source Premier, Web of Science, and Scopus. There were 94 eligible articles that met the criteria related to the second study. However, among these articles, 26 were outside our research objective (such as textile machinery, design, clothes, and classification). Apart from the 26 articles, other articles that lacked proper information regarding the methodology and results of the implementation of lean were also excluded. The remaining 14 articles focused exclusively on lean tool implementation and the effects on productivity and/or OHS. Then, these articles were double-checked using Google Scholar, and their bibliographies were also checked. During the double-checking process, four more articles were added to the existing article list for a final number of 18.

3.5.3. DATA COLLECTION IN THE INTERVENTION PROCESS (STUDY III AND IV)

Study III and IV were fully based on the intervention data. Data collection in the intervention process was divided into two stages, one was the baseline data from the pilot line before the start of the intervention or lean tool application, and the second was the data collection after the intervention. Additionally, our observations, interviews, and logbooks were used for obtaining data. Table 6 provides an overview of the productivity and OHS data collection.

Table 6: Data collection overview

Tools	Data collection procedures before and after the intervention
Time and motion study	The cycle time of each process was taken three times using a stopwatch and video recording.

5S	An audit sheet was used for assessment of the production floor.
VSM	A garment piece was chosen from a bundle and the throughput time was measured, which means the start to end time of any complete garment product.
SMED	Measurement was taken of the time from the end of an old style up to the start of the changeover to a new style. Then, the time was measured again until they had final products without defects. In more detail, every process complementation time was taken several times until every single process was defect-free. In this way, we collected data up to the last process and summed the total time taken for changeover.
Worker questionnaire	Ten questions were used for musculoskeletal pain and fatigue, and scores were given as 0, 1, and 3 for no pain, sometimes pain, and always pain, respectively.
Observation (ergonomics conditions)	Data were taken on whether there was enough space between workstations; machine safety; material handling; and housekeeping. All were given scores ranging from 1 to 5.

The productivity data collection consisted of Time and Motion Study (video recording and track sheet maintaining), 5S audit sheet (Hammad Saeed Shamsi, 2014; Quddus & Nazmul Ahsan, 2014; Vijayakumar & Robinson, 2016), VSM, and SMED. TMS data were used for efficiency calculations of the production line. The 5S audit sheet mainly focused on input racks; obstacle free aisles; organization of sewing stations; removing all unnecessary items; status of all required documents; and electrical wires. For data collection for VSM and SMED, a detailed description of calculation procedures was provided to the operation teams. One observation format was made to track production data daily. For OHS and ergonomics data collection, we used a template based on the ILO guideline (ILO, 1998; ILO & IEA, 2010).

Moreover, participants' musculoskeletal pain and fatigue scores were designed according to Corlett and Bishop's body chart (Corlett & Bishop, 1976), which was used during the interventions (for Study III). The survey questionnaire is a highly structured method where researcher bias is limited. The questions included whether respondents had fatigue and musculoskeletal pain in the neck, buttocks, upper and lower arms, upper, mid, and lower back, and more. The survey questions were asked face to face to assist with the respondents' attention, and furthermore, if they did not understand something then this created an opportunity to discuss it. In addition, short interviews were conducted with the workers of the pilot line, the focus of which was possible health consequences after lean tool application with OHS consideration; each short interview last approximately 15–20 minutes.

Furthermore, research team members questioned the workers and supervisors individually about what types of problem they met during lean tool application with OHS, in addition to overall support from management (for Study IV). I used the semi structured interview format because of its flexibility, which helped interviewees to express their perspective regarding the application of lean tools in their own words. I interviewed over several days and each semi structured interview was approximately 1 hr.

In addition, the research team maintained a shared logbook, in which all contact with the company was written down. This included telephone contacts, meetings, activities, materials, and data received. The logbook also includes observation from activities performed during the whole baseline and intervention study. After each meeting, training activity, and implementation activity, the research team wrote a summary of the observations: what happened, how it was received in the company, and what the outcome was.

3.6. DATA ANALYSIS

Study I

For this thesis, the first study focused on the complementarities between operational and OHS practices in the garments industry of Bangladesh. The study followed a mixed method of both qualitative and quantitative analyses for accurate data analysis within 50 garment manufacturers in Bangladesh.

Both operational and OHS sets of practices comprised technical and behavioral aspects, consisting of an assessment model of five-step progression with the overlapping practices of leadership commitment and communication. After creating the sets of practices for the factories, a qualitative data maturity assessment for both the OHS and operational practices were created based on the in-depth interviews, following observations and production of the factories. Ph.D students and research assistants conducted the in-depth interviews, and after finishing the interviews they translated them from the local language to English as soon as possible. An assessment was performed based on the obtained data from interviews and a score was given for individual items. In addition, each researcher was given an assessment score based on observations on the production floor. With a combination of in-depth interviews from managers and researcher observation scores, a final score was made. Quality control of the observation score was performed by the Bangladeshi and Danish senior researchers. This score was analyzed for a statistical test to better understand the two variables.

In this study, we performed statistical analysis using SPSS V.25.0 to determine whether a correlation existed between OHS and operational practices. To show this co-relationship, we analyzed the descriptive statistics and Pearson coefficient. The average maturity level scores of both OHS and operational practices were evaluated using the Pearson coefficient of correlation. Furthermore, we checked the existence of a linear relationship using a linear regression line, homoscedasticity, and normal distribution between the two variables. Descriptive analysis and Pearson coefficient were used to investigate the effect of plant size (large, medium, or small) on operational practices and OHS. For further clarification, we also investigated general linear model (univariate) analysis for the plant size.

Study II

The final 18 articles were analyzed in parallel according to four main classifications: strong evidence for positive or negative and weak evidence for positive or negative associations between lean and OHS. This was done following the procedures or classification made in an earlier review of lean and working environment (Hasle et al., 2012). If solid indications such as mixed-methods, experiments, and multiple case studies were found in the reviewed articles, they were classified as strong positive or negative cases. On the other side, if the reviewed articles focused for example on only single cases or had a weak methodology, they were considered weak evidence for positive and negative classification. In addition, we added another category for articles with no information about the outcomes of productivity and OHS.

Study III

To understand which factors have acted in regard to the lean application effect on worker health in the RMG sector, we performed an analysis on six factories' data in the second-wave intervention. I used qualitative data to identify what they actually changed in the work. The interviews were recorded, transcribed from the local language to English, and read thoroughly several times to understand the application of lean tools and possible effect on workers' health. To better understand the interviews, I also performed statistical analysis for pain and fatigue survey data. After obtaining the participants' scores of muscular pain and fatigue, I analyzed them with SPSS V.25.0. These pain and fatigue scores were analyzed using descriptive statistics with a paired sample *t*-test for before and after measurements of the intervention.

Furthermore, for the production data TMS for efficiency measurement, 5S and VSM were analyzed before and after the intervention. In TMS, I used the mean cycle time and worker capacity to find the Standard Minute Value (SMV). The SMV is used for the calculation of efficiency. In addition, an Excel simulation was used to find bottlenecks for the TMS. We also conducted problem analysis of worker operation by observing video recordings. For 5S, after obtaining the audit scores, we analyzed the problem on the production floor according to our audit parameters and made a priority list of problems on the production floor that are crucial to solve. For another tool VSM, I used throughput time to analyze the waiting time and percentage of value- and nonvalue-adding activities for each process, and finally summed all waiting and value-added time into total throughput time. In addition, based on the current analysis of throughput time, I made a future state map in the sewing line. Moreover, I analyzed the ergonomics condition of the sewing production floor. On the production floor, the space between adjacent workstations was analyzed and compared with the standard gap between two workstations; furthermore, I analyzed the machine safety guard, pickup and drop-off material, and bending of the angle from workstation to workstation according to ILO guidelines.

Study IV

Data analysis for this study included quantified production data maintained in the daily logbook. Additionally, the semi structured interviews were recorded and transcribed from the local language to English. We conducted an analysis on the two-wave intervention data: two from the first-wave intervention, another two from the second-wave intervention, and finally data from 6 months later for sustainability.

In this study, data analysis of the whole intervention process was performed with two dimensions. The first was to determine the intervention outcome. I started by conducting a before-and-after analysis. The changes in before and after production data were quantified using the following scale from baseline: No change (N) < 5%; Low (L) = 5%–less than 15%; Medium (M) = 15%–25%; and High (H) > 25%. Additionally, I took intervention fidelity data that were assessed by our observations of the factories' commitment to how they would implement the suggestions. The scale used for measuring fidelity was similar: low (L) = low fidelity; medium (M) = medium fidelity; and high (H) = high fidelity. The second dimension was CIMO logic (Denyer, Tranfield, & Van Aken, 2008; J. Van Aken et al., 2016). The idea of CIMO in this study was an iterative process where I compared differences between the companies. Then, I examined the differences in contexts and interventions. From this analysis, some possible mechanisms that facilitated the possible outcomes could be observed.

CHAPTER 4. FINDINGS

This dissertation contributes to the knowledge on the possible synergies between productivity and OHS that are facilitated by lean in the RMG industry of Bangladesh. The main results from each study are presented in this chapter. The empirical findings from the four articles match the four RQs. In Figure 3, I show how the four articles are interlinked.

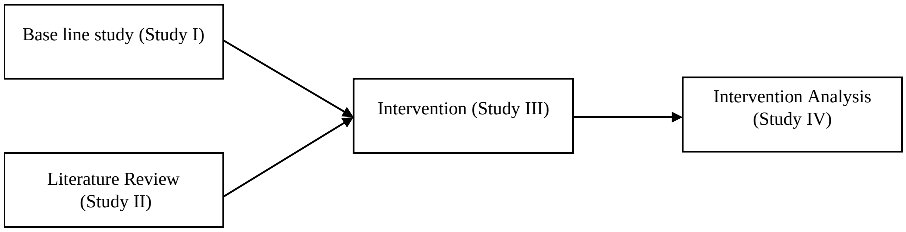

Figure 3: Four-paper interrelation model.

The first study examined the maturity level of operational practices and OHS modified by plant size and was conducted using mixed-methods. Parallelly, in the second study I performed a literature review where I focused on lean tools' effect on productivity and OHS as well as the relationship between them. After obtaining a clear picture from the literature review and baseline study, I made an intervention design within the project framework and I applied some of the lean tools in the RMG factories. Finally, I assessed the productivity performances and possible OHS consequences in my third study. When implementing a bundle of lean tools in this specific context, I faced many challenges, and therefore in my fourth paper (on Study IV), I present the mechanisms of successful lean implementation in the RMG sector. More detailed findings from the four studies are presented in the following sections.

4.1. STUDY I

This study mainly focused on a group of garments manufacturers in Bangladesh to determine the current maturity level between OHS and operational practices. Fifty small, medium, and large garment factories were chosen according to factory selection criteria. Two parallel lists of practices named as "Operational Practices" and "OHS Practices" were developed to find the maturity level.

The findings of this study were as follows. A co-relationship did exist between operational and OHS practices. This is the first finding of its type because such a study has not yet explored these factors, either in Bangladesh or other developing countries.

Moreover, the overall findings indicated that factories with a high level of maturity of operational practices had a high maturity level of OHS practices, and vice versa (see Figure 3). This was tested using Pearson coefficient analysis. Even though they are generally positive relationships, it did not show all the factories that have that relationship. More details from Figure 3 indicate that a limited number of factories also had high OHS performance but their operational performance was of a medium level. Similarly, a limited number of factories also had high performance in operational practices but a poor OHS maturity level. Therefore, it is not always true that factories with high operational performance always have superior OHS practices.

In addition, relevant studies have indicated that plant size has an effect on operational performance and workplace safety (Levine & Toffel, 2010; Shah & Ward, 2003). Thus, I investigated plant size's effect on operational and OHS performance. The findings on the effect of plant size on maturity levels showed that large factories had a significant correlation (two-tailed significance value = 0.000), medium-sized factories had marginal significance (two-tailed significance value = 0.037), and small factories showed a nonsignificant relationship (two-tailed significance value = 0.161).

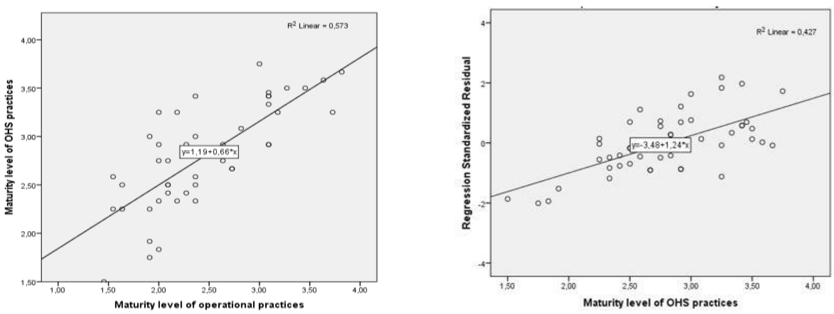

Figure 4: Maturity level of operational practices and OHS.

In addition, the results revealed a significant correlation for large factories, and clearly large factories presented a superior fit around the linear line compared with the medium-sized and small factories, as can be seen in Figure 4. Therefore, the integration between OHS and operational practices is more successful in larger plants; one possible reason is their greater access to human and financial resources.

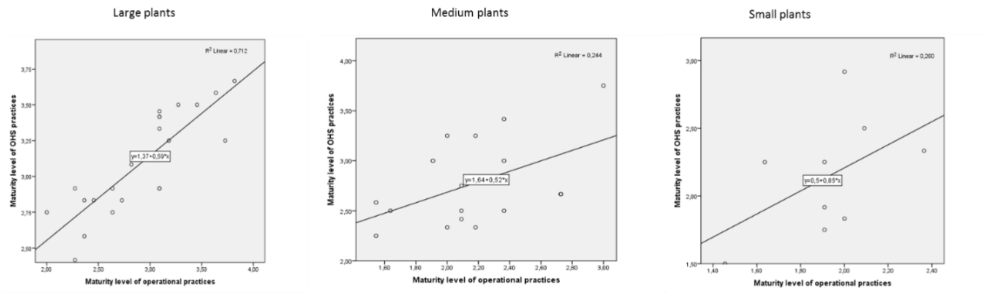

Figure 5: Maturity level of operational practices and OHS with plant size.

However, large plants did not always exhibit good performance and a strong co-relationship in both dimensions. The reason why this must be mentioned is that if there was an automatic co-relation as a plant became bigger, all the problems could be solved, but that is not necessarily so. Moreover, some large factories put emphasis on OHS and obtain good performance, whereas some pay less attention or have fewer qualifications and are below average; furthermore, some of them have better performance in one dimension but not necessarily in the other one. Regardless, it is true that operational performances and OHS seem to be related for large firms also in the context of developing countries.

4.2. STUDY II

This study was a literature review, and the whole summary of its findings is based on a previous review paper (Hamja et al., 2019b).

This literature review study highlighted lean tool implementation on the garment production floor associated with the productivity and OHS consequences at the same time. The review paper also included the outcome of the implementation of lean tools and outcomes of productivity and OHS. In total, 18 studies from peer-reviewed journal articles that focus on lean implementation in the RMG sector were analyzed. Table 7 presents a summary of all 18 studies and the findings for RQ 2.

Table 7: Summary of the findings of RQ 2.

Assessment Criteria	Strong association	Weak association	No information about productivity/OHS	Total number of articles
Positive association with productivity	8	8	2	18
Negative association with productivity	0	0	2	18
Positive association with OHS	5	9	4	18
Negative association with OHS	1[a]	1[a]	4	18

Note: a = Two articles reported mixed results (both negative and positive associations between lean and OHS) in the selected 18 articles.

The findings of this review paper regarding productivity were as follows. After lean tool implementation, 16 studies reported positive outcomes in terms of productivity in garment factories. Additionally, most studies did not contain any in-depth method for studying how lean was implemented in the RMG sector. Most papers only emphasized the survey data collection. In most cases, they did not ask workers but only supervisors, and did not contain any information about workers points of view or did not indicate information about before and after lean application in the RMG sector. Most of articles focused on different lean tools' effects on productivity and a limited number of articles performed simulations for future production mapping using VSM, which do not give exact information about real-life lean application in a specific context.

Regarding the findings on OHS, there was no indication of adverse effects of lean on OHS, which is expected in the early lean and OHS literature. Again, most of the literature indicated a positive direction of worker health. In addition, another critical finding was that most of the articles mainly focused on a possible problem in the psychological factors of lean application, and a limited number of articles concentrated on workers' physical-related hazards such as worker movement, sitting position, and cleanliness. Although two studies showed both positive and negative results after lean application, one article reported a strong negative argument about psychological factors after lean. This study also found a methodological limitation, which was present in most of the articles. Additionally, no study indicated the long-term health effects or RSI risk after lean application. Moreover, productivity and OHS sustainability were generally not studied in the reviewed articles.

4.3. STUDY III

In this study, an intervention was performed in six garment factories in Bangladesh, where TMS, 5S, and VSM were implemented. The aim of the study was to contribute knowledge about the effects of lean tools application on productivity and OHS in Bangladeshi garments factories. A whole summary (Hamja, Maalouf, & Hasle, 2019a) of the findings based on the intervention study (Study III) is provided below.

The findings of this study are presented Table 8. Most factories exhibited improvements in value-added time, whereas for one factory it remained constant. Two factories (F-2 and F-5) implemented all actions as we suggested and obtained the highest percentages of improvement (80% and 100%, respectively) of value added in the total cycle time. In terms of 5S scores, one factory (F-2) exhibited the highest percentage of change (22.4%) because it implemented the full range of actions we suggested for improvements. The lowest result was 10.3% by factory F-4, which had problems applying the actions because of a shortage of available space. For another tool, TMS, the efficiency range changed from 2.5% to 26% for all factories. The highest efficiency was 26%, which was achieved (F-2) because the factory implemented most of the actions for improvement, including cell formation and management support. For instance, the company that achieved the highest result used systematic TMS and solved targeted bottleneck saving times between 1 to 11 sec/cycle. As a result, the capacity of workers in a bottleneck process increased by up to 32% per hour. Overall, the efficiency finally increased by 26% in that factory.

Table 8: Summary of intervention results.

Lean tools	% of change					
	F-1	F-2	F-3	F-4	F-5	F-6
VSM	42	80	33	50	100	0
5S	12.7	22.4	21.8	10.3	21.4	14.5
Efficiency	14.7	26	14.9	8.2	2.5	5.3

For OHS, to obtain indications of the effects on fatigue and health, we administered before and after questionnaires to workers. The results of the questionnaire were transformed into scores. When we compared the before and after scores, we found that in all six factories, workers had reduced fatigue and pain, and this was supported by the statistical analysis (see Table 9). Moreover, the results of paired sample *t*-tests showed significant p* values (p* < .05) for all factories, which meant that pain and fatigue scores were reduced on a short-term basis.

Table 9: Participants' mean scores of pain and fatigue, and *t*-test (pairwise comparison) values before and after the intervention.

Factory	Mean Score		Std. Deviation		Pairwise comparison (*t*-test)
	Before	After	Before	After	Sig.(two-tailed) p^*
F-1	8.03	6.08	4.86	2.45	0.030
F-2	5.1	3.57	2.60	2.14	0.009
F-3	5.46	4.58	3.26	2.80	0.015
F-4	5.11	4.11	3.91	3.20	0.004
F-5	1.72	1.13	2.57	2.57	0.000
F-6	8.29	5.52	5.18	4.01	0.044

Note: Significant value $p^* <0.05$

In addition, I performed an assessment of possible OHS consequences of tangible changes based on the worker interviews and recommendations about work postures that represent good ergonomics. The results showed that most of the changes may have had positive or neutral effects on OHS (see Table 10). Some changes had positive effects as well as reduced the risk factors. For example, indications of adverse effects were not seen for VSM and 5S, but the effects could be more confusing in TMS. Moreover, the total results of the changes may not have had effects on short-term exposure, such as muscular pain.

Table 10: Actions, lean tools, assessment of OHS consequences, and reasons for the assessments.

Action in the sewing pilot line	Applied lean tools	Assessment of OHS consequences	Reason for assessment
Bundle size reduction	VSM	+	Easier to pick up and drop materials, resulting in fewer awkward work movements (bending, twisting, and stretching).
Keeping extra bobbins in the workstation	VSM	0	Reduces extra movement for picking up bobbins from another place.
Supply auxiliary machine tools	VSM	0	Auxiliary tools are time saving and increase the quality of work (more precision).
Control of WIP between workstations	VSM	+	Increased visibility, facilitating picking and dropping of bundles.
Standardized tool storage system	5S	0	Facilitates picking up of necessary items.
Removing unnecessary items	5S	+	Creates more space (easy movement), increases visibility, and reduces risk of accident.
Redesigning/rearranging workstations	5S, TMS	+	Facilitates pickup and dropping of bundles before and after completing work. Improves work postures and movements.
Adjustable chair	5S	+	Improves sitting positions with support and adjustment to body size.
Cleaning workstations	5S	+	Keeps workstations and the shop floor clean and free of dust; reduces the risk of respiratory exposure and accidents.

Labeled input/output rack	5S	0	Labeling helps to identify the flow of WIP more easily.
Keeping racks and bins in specified place	5S	+	Reduces risk of accidents.
Operators' sewing skills	TMS	+	Reduces exertion in performing work tasks.
Removing unnecessary activities	TMS	0 or -	Depending on the task, removing a similar task will have a neutral effect, but there may be a tendency for less variation.
Quality control performed by operator	TMS	+	Increases job variation.
Reducing/adding helper	TMS	+ or -	Depending on the actual change, reducing helpers may create task overload, but it also creates more variation in tasks. Adding a helper may reduce overload, but also creates less variation.
Keeping bundle on thigh	TMS	+	Reduces stretching, twisting, and bending.
Cell formation by job sharing/merging	TMS	+	Increases multi-skilling and variation.

4.4. STUDY IV

The aim of Study IV was to examine the differences in the outcomes of the interventions and their possible causes, as well as to identify the mechanisms for successful lean implementation from the analysis of differences.

The analysis of the data based on the CIMO model was presented in the methodology chapter. The analysis of the context, intervention, and outcomes led to identifying the mechanisms. The major factor in this specific context that influenced the way the factories implemented lean was factory size differences; thus, a larger factory would have a higher number of Industrial Engineers (IEs), but this number of IEs may not be enough for running a business smoothly. Other major factors were a shortage of skilled workers and competent management (particularly IEs) in traditional operation and lean operations. Moreover, a labor union was active in one factory, whereas two factories had delays in their payment systems for workers' salaries.

During the intervention, the four factories implemented lean in quite different ways. Some of these were influenced by differences in context, and also in the second wave I added more activities to strengthen the intervention outcomes of that wave. The findings of the intervention were as follows. Among the four case factories, only F-3 went with the intervention suggestions as much as possible and achieved the best outcomes in terms of productivity and OHS.

In terms of productivity, F-3 achieved the strongest outcomes; F-2 and F-4 had weak outcomes; and finally F-1 achieved almost no improvement. In terms of OHS development, the outcomes varied across the factories, with F-1 and F-3 having the highest improvements and the other two factories were between them. Differences in outcomes across the factories were mainly due to the differences in their contexts, the differences in the intervention caused by their own decisions, and because of my changes in intervention from wave 1 to wave 2.

Based on differences between outcomes, contexts, and interventions, this study identified 23 mechanisms (see Table 11) that are essential for lean application in the RMG sector. Results from these mechanisms showed that F-3 was superior to the other three factories.

Table 11: Mechanisms for successful lean application in the RMG sector.

Local factor for successful lean application	Mechanisms	F-1	F-2	F-3	F-4
Top management (TM) commitment	Daily visit by TM to the production floor	L	M	H	N
	Daily informal talks with workers when TM walk around on the production floor	N	L	H	N
	Open discussion of TM with line supervisors	N	L	H	L
	Attention of TM to instant solutions to worker problems	N	N	M	N
	TM decision to ensure one IE always present during production time on the floor	L	M	H	L

Worker involvement	Empowerment of the worker (share their problems)	N	M	H	N
	Workers' awareness of OHS and knowledge sharing with others (own physical health)	N	H	H	L
	Provision for small gifts for best performance to workers every month	L	N	H	N
	Respect among workers (not shouting)	N	N	M	N
Training	Formal training for workers	N	H	H	L
	Floor level implementation after formal training	N	L	H	L
	Offshore training	N	L	H	N
	Using more visual and adaptive training methods	N	L	H	L
Tools and methods	Dynamic Operation team	L	L	H	L
	Practice of best methods in sewing	N	M	M	N
	Standing maintenance team during changeover	N	L	H	N
	Adoption of new auxiliary tools	N	L	H	N
Learning culture	New idea generation and execution by supervisor	N	L	H	N
	Materials in-house follow-up culture	N	M	M	M
	Monthly to weekly production planning	L	N	M	N
	Weekly meeting and for problem solving	L	M	H	N
	Benchmarking new ideas from another factory	N	L	H	N
	Collaboration between internal and external factory	N	L	H	N

In more detail, Table 11 shows possible mechanisms for successful lean application, which were derived by comparing the four factories' outcomes. The analysis was an indication that the factories applying these mechanisms probably have the best position to ensure sustainable lean application. Therefore, a relationship exists between applying these mechanisms and then having a greater possibility of sustainable lean implementation. The factory with the best outcomes for the direct lean intervention has also taken further measures, which indicates a more long-term sustainability. Because we have not followed up with them for a long time, we do not know the true situation about their sustainability. However, we attempted to make an assessment and determined that it is likely they will be more sustainable. The findings in this study also indicated that one factory was more sustainable than the others.

CHAPTER 5. DISCUSSION

The aim of this research was to identify the possible synergy between productivity and OHS facilitated by lean application as well as the possible consequences on OHS in the garments industries of Bangladesh. Specifically, the research addressed the problem of how the operational improvement practices complement the OHS practices in the garments industry and vice versa. This was done to discover how productivity in the garments industry can be improved by adopting lean tools, as well as whether OHS improvements complement or contradict production improvements. Additionally, this research sought to determine the possibility of obtaining long-term sustainability by considering OHS. This research also addressed the difficulties of adopting and applying lean tools for productivity improvements and OHS in the garments industry of Bangladesh. This chapter of the thesis discusses the implications of the findings, and how they add value to the continuous endeavor to develop the productivity and OHS practices in the garments industry. I do this by discussing the implications of each of the four studies, followed by discussing across the studies with methodological considerations and finally adding advice for practitioners.

5.1. DISCUSSION ON THE FINDINGS

Complementarities between operational and OHS practices

This is the first study to show that a positive co-relationship exists between operational performance or productivity and OHS practices in developing countries. Previously, this has only been studied in the context of developed countries (Pagell, Johnston, Veltri, Klassen, & Biehl, 2014; Veltri et al., 2013). Regarding possible explanations for this co-relationship also existing in developing countries, it is possible that—similar to what Pagell and colleagues showed—the two factors are related and contribute to each other. However, in addition to this explanation, a special situation appeared in Bangladesh because of the Rana Plaza accident. This created strong institutional pressure to improve OHS, which may have influenced OHS receiving higher priorities compared with other developing countries without this institutional pressure. The point is that if there was not increased institutional pressure to do something about OHS, then maybe the co-relationship would not have been so strong. Therefore, it has also to do with management decisions and their capability in operations and OHS practices. For instance, some of the factories had lower operational and OHS practices, indicating that management had not assigned high enough priorities to these practices. Another possible explanation for lower operational and OHS practices could be that those factories have recently started production or are doing subcontracted work for other factories.

To better understand the co-relationship between productivity and OHS, it is also important to consider the factor of factory size, which modifies the co-relationship.

The co-relationship was stronger for larger factories; as the companies grew, the operational and OHS practices improved. Moreover, in the cluster analysis, the larger factories tended to have a better practices in both factors than did smaller factories. Larger companies probably have more resources, and thus they have a better chance of improving both practices and utilizing the possibilities of correlations. Additionally, large factories are more concerned about the global competitive market and they probably have more resources to invest into training and hiring competent personnel from different countries. However, in our analysis, we also found larger factories with weaker co-relationships, which indicated proper factory policies, strong management decisions, and qualifications of improving both productivity and OHS might be the key factors rather than only size. Another explanation may be that large factories having more resources does not ensure that they invest them to improve OHS practices, for which they are probably struggling to maintain business competitiveness. In smaller factories, possible explanations for a weaker co-relationship are lower institutional pressure, weaker law enforcement agents, and weaker human and financial resources compared with larger factories.

Finally, another crucial discussion is the methodological consideration. This study employed a small sample (50) as representative of the total number of exporting factories registered by the BGMEA. Therefore, for statistical reasons there may be variations or difference in other factories outside of the sample. In other words, this sample size is not sufficient for making generalizations. Moreover, factory to factory may vary within the same country or in the same context in developing countries. Therefore, it is very difficult to say whether this result is applicable for all developing countries, but it is true that this study is an indication for further studies.

Lean tools' effect on productivity and OHS—Literature review

Regarding productivity, this review article confirmed the same findings as several other studies in that a positive co-relationship between productivity and lean exists. However, it is possible that there is no certainty that companies always achieve this positive co-relationship because of the differences in contexts, cultures, implementation processes, and other, which are important for outcomes.

Nevertheless, long-term effects on productivity were not studied. Thus, sustainability with full application of lean has not actually been observed in some of the studies on garments industries. Moreover, the general experience with lean in developed countries reveals many failures in implementation and does not obtain the expected benefits (Hasle et al., 2012; Hopp, 2018; Mostafa et al., 2013), which may have been the case here as well. Furthermore, developing countries are known to have a strong top down approach, which possibly makes it difficult to implement lean. However, if the top management has a good understanding of lean, this may provide an advantage because they have the power to decide or secure what occurs in the factory. Moreover, literature has indicated the need for capability development of a firm for the sustainability of lean application (Jørgensen, Matthiesen, Nielsen, & Johansen, 2007; Kleindorfer, Singhal, & Wassenhove, 2005). The limitation of the 18 articles was that they mainly focused on lean application but not on capability development. Another way to achieve sustainability is continuous improvement (CI). Research has shown that CI is a crucial factor for sustaining lean in a process industry (Bessant & Caffyn, 1997; Dabhilkar & Bengtsson, 2004). Moreover, most of the reviewed articles focused on the short run and did not follow up in a systematic manner; as a result, success from lean is difficult to sustain.

In terms of OHS consequences, it is critical to mention some contradictions existed in some lean studies. We found 14 papers that indicated positive relationships between lean and OHS. However, two of them indicated ambiguous results for worker health and psychological effects in the RMG sector. Different studies in different sectors have also shown that integrating OHS with lean helps in successful lean application as well as worker health, behavior, and psychological factors (Bessant & Caffyn, 1997; Sakouhi & Nadeau, 2016; Sawhney & Chason, 2008). Therefore, previous studies are a guideline for lean implementation with OHS considerations. The garments industry is known to be a highly repetitive work sector, and thus there is a great chance of occupational injuries. If lean runs in the long term in an industry, workers will have the chance to develop RSIs due to highly repetitive tasks in the RMG sector, and the effect on workers' health and psychological problems will become clear, which was not studied in the articles I reviewed.

Effects of lean tools application with OHS integration in the garments industry

Based on the baseline study and literature review, we designed an intervention. This intervention was performed in six garment factories to determine the practical experience of lean tools application and its effects on both productivity and OHS. Notably, the study results were in accordance with the literature review. Regarding productivity, we obtained the same results as in the literature review, and regarding OHS, we generally obtained positive consequences, although some showed ambiguous results compared with the literature review. This is in accordance with the findings here, because the assessment of lean effects on OHS showed that some TMS changes may have negative consequences. We performed an assessment on some of these TMS changes, which showed that in some cases, TMS has neutral or negative effects because of the "ergonomic trap." Specifically, the ergonomic trap is created by TMS improvements in ergonomic factors such as risks and design changes (O'Neill, 1999), which is when stress on workers increases due to the improvements in work speed through ergonomically improved workstations. In other words, using TMS to reduce waste in the form of micro breaks, the repetitive element of the work increases and thus also the risk of RSI. Therefore, in addition to the redesign of workstations, breaks and variation might be required.

This study reported positive feedback after the changes introduced by the intervention, but this was only after short-term exposure that we could measure the effect on musculoskeletal pain. We do not know what will happen in the long term. Several reasons may exist for the positive feedback. One is that 80% of the garment workers were aged between 20 to 25 years; at this early age they can recover quickly, or they have probably only worked for a few years, and thus their pain may not have not become chronic, which is why they can easily recover. The main reason could be that the work became easier for them after the interventions; however, if they have worked for 20 years, they may have same level of pain but it may be chronic. Even though the intervention resulted in relief in the short term, long term exposure may cause RSI.

Moreover, the extensive attention workers experienced due to the intervention both from management and researchers helped the workers psychologically. This scenario can be explained with the so-called "Hawthorne effect" (Kompier, 2006), where positive effects are caused more by social attention than by interventions. Such an initiative may have by itself improved their wellbeing.

The assessment showed not only positive effects on OHS, but also tools such as TMS and 5S reduced risk factors for OHS such as accidents and dust. In repetitive work such as sewing, ergonomic improvements make works easier, which in turn may increase the speed and intensity of the work. This can open up risks for increased long-term exposure, leading to chronic MSD and other health problems. A part of the solution might be controlled by optimizing worker involvement, but in a developing country such as Bangladesh this is difficult to maintain because of the lack of a tradition for involvement of workers and unions.

In conclusion, we did not find any adverse effects on OHS, and we assumed a positive effect at least in the short term. However, to determine the long-term effects, further studies are required. In addition, managers must be very careful to design in such a manner that limits exposure to repetitive work to a low level, with as much variation and as many recovery breaks as possible. Otherwise, the risk of long-term effects may be high. Moreover, this study included a pilot line with a total of 192 workers. Covering a higher number of workers would probably have shown more solid results. Another critical issue is that this study used three lean tools, but we do not know the effect of other lean tools on OHS. We accepted a positive effect of SMED and TPM and negative effect of JIT on workers' health, but this also requires further investigation with a combination of other lean tools. TPM could, for instance, be important for maintaining sewing machines because they have a great chance of needle injuries. Therefore, if the machines were properly maintained using the TPM concept, this could reduce needle breakdown and injuries as well as maintain smooth productivity. Moreover, various researchers have suggested that TPM and SMED have positive effect on productivity (Bajpai, 2014; G. L. D. Wickramasinghe & Perera, 2016) in the garments industry. This indicates that there could be a great chance to reduce the risk of occupational injuries as well. Thus, this study indicates the need for further research on the long-term effects of lean tools on both productivity and OHS.

How can lean practice be transferred to the garments industry in Bangladesh?

Based on the intervention, this study analyzed the successful lean implementation factors. This intervention was conducted in two waves and selected four factories. This was because an iterative method was followed for the intervention, where after the first wave the intervention outcomes were analyzed to modify the intervention to secure better outcomes in the second wave. This is the design science research approach (J. E. Van Aken, 2004), which examines the outcomes and then looks back again to see what can explain the outcomes to design a more accurate intervention design in moving forward. Looking forward helps to make novel innovations and looking backward helps to create and clarify the results (Kaipia et al., 2017).

We have five main general recommendations for successful lean application, which were generated from the lean literature: top management commitment; worker involvement; training; tools and methods; and learning culture. For the four different companies, we also have four different outcomes in terms of implementation of the general recommendations. Additionally, we looked at their own activities to follow the guidelines in practice. For instance, we observed what the top management did differently in the four companies, such as whether the executive director-level manager visited the floor every day and had a short informal meeting with the workers, which may have helped the successful lean implementation. We also compared the differences in workers involvement and participation, training, tools and methods, and learning culture. For example, we observed the differences in worker empowerment and OHS awareness in the four companies. We also compared how differently the workers were maintained and the operation of teams. We compared these differences and deduced the mechanisms for successful lean application in the local context, that is, Bangladesh.

The crucial finding was that we saw that one factory, by following the general guidelines strictly and further adding their own activities for lean implementation, was highly successful compared with the others. This may support the process of identifying the mechanism and may explain why the outcomes were different in the other factories. This factory practiced top management commitment strongly, and hence showed excellent outcomes. In general, top management in developing countries such as Bangladesh talk more than practice commitment, which may be a reason why some factories did not obtain the expected benefits of lean. Similarly, worker involvement is a difficult issue in Bangladesh because there is no such tradition. However, this successful factory has taken some initiatives to involve workers from the top management level. The top management maintains a track sheet containing daily worker activities, suggestions, and solutions of the workers, which are acknowledged by the top management the following day. Similarly, in the case of other recommendations, we found the successful factory to take strong initiatives, which is a possible reason for achieving better outcomes compared with other factories.

Another issue is sustainability; because there is no prospective long-term study in the literature, and this was also not possible in my study, the sustainability is unknown. However, we have some indications. We scored factories in terms of their potential with productivity and OHS expansion to generate an indication of their sustainability. Some factories took the issues seriously and took strong initiatives in terms of top management commitment, worker involvement, and others, and thus if they continue following the mechanisms properly they may have a greater chance of sustainability. In addition, factories that applied the mechanisms along with the OHS and ergonomic guidelines possibly built a stronger foundation for sustainability.

Moreover, our analysis showed that the factories that achieved higher scores in OHS and ergonomics also gained higher in sustainability. However, our analysis showed a low score for one factory in sustainability despite it having high scores in OHS and ergonomics. A possible reason behind this scenario could be that the factory emphasized OHS and ergonomic issues more than productivity because of pressure from the buyers' side.

5.2. METHODOLOGICAL CONSIDERATIONS

The main strength of this study is that was conducted in a real-life situation with the application of lean tools and integration of OHS in garment companies. For this study, I used different data collection methods that can be used for triangulation in the analysis, thereby strengthening the validity of this study. This is because I employed both qualitative and quantitative methods; moreover, I was directly involved with workers to collect data and stayed the whole day to make the workers feel free to express their feelings. My activities possibly supported me in obtaining more accurate data. Another strength is that production data were collected several times before the final data collection. Part of the intervention was that I followed up the data collection process and measured the production data several times to provide feedback about the lack of lean tools application to the companies, thereby strengthening the intervention.

In addition, I administered interviews face to face, which helped me to understand the interviewees' feelings and whether they faced any problems during the interview or data collection. Furthermore, I made clarifications several times, which also helped obtain accurate data. Additionally, I used videos of production data (TMS, 5S, and VSM) and audio recording (interviews) for data collection, which helped me to analyze the data accurately. To sum up, all the data collection and analysis methods used in this study were the strengths. Thus, the possibility of data bias from incorrect data collection is low because the data were collected several times.

However, some limitations still exist in this study. For the baseline study, one barrier was that I could not obtain data from the company about their past practices of productivity and OHS. Most of the companies do not have any policy to preserve their data regarding productivity and OHS. This, it was difficult to obtain more than 6 months to 1 year of data for further trend analysis. Therefore, I had to focus the assessment on what I could observe and measure, as well as on information from the interviews. Some further problems related to data collection during the intervention concerned factory management and workers. Specifically, sometimes the workers were reluctant to give an interview because they thought would lose their job if they shared any information. In addition, most of the workers' education levels were below secondary school and they were always afraid to say anything. However, I assured them that the interviews were highly confidential and there was no risk of them losing their job. One more limitation of this research was that when I was on the production floor, workers were in a hurry to work; moreover, some were showing me they were highly active in their job because they thought that I would report to the top management. However, I informed them there was no need to hurry, visited several times to make it easy, and gave several lectures about the aim and objectives of this study. Another limitation was that it is a pilot line study, and thus resembles many of the studies found in the reviewed papers, which were mainly in pilot studies. This leads into the research implications of this study.

The results from this study have sufficiently high validity and can be trusted, but there are also limitations when it comes to generalization to other factories and other countries. Therefore, there now exists a great need to conduct a longitudinal study of the effects of lean applications on long-term productivity and OHS of workers.

5.3. RESEARCH IMPLICATIONS

This dissertation provides insights into the application of lean tools with OHS integration in the RMG industry of Bangladesh. The results showed positive effects on productivity and no negative effects on worker health in the short term. Furthermore, 23 mechanisms were identified for successful lean application in the RMG sector with OHS integrations.

In this study, there was no adverse effects of lean tools on workers' health; however, it is still unclear what the effect on worker health will be in long-term applications of lean. Therefore, because knowledge is lacking on the long-term effects of lean on OHS and productivity, future research should focus on identifying the long-term effects of lean application and potential risks to workers' health in the RMG sector.

In this study, our analysis suggested 23 mechanisms for successful lean tool applications in the RMG sector. Future research should focus on a large sample size with both qualitative and quantitative analyses of the mechanisms. A more in-depth research study in the RMG industry would strengthen the actual relevant mechanisms and possibly both qualitative and quantitative analyses. Furthermore, future research should examine whether there are other potential mechanisms that are vital for better outcomes in the RMG industry. To further understand these mechanisms, they could be applied in other manufacturing or processing industries.

Because my study was in the short term, the sustainability issue was absent. We observed whether the factories under investigation were expanding the lean initiative from the pilot lines to other lines after the intervention. This indicated how the factories are shaping themselves to attain lean sustainability in future. Future research should study the effect of lean on OHS and ergonomics and productivity in a broader spectrum to indicate whether it is a sustainable process in the longer term. Furthermore, research can be directed to formulate sustainable lean designs to integrate workers and working conditions.

This study was performed in 12 RMG factories in Bangladesh, revealing valuable insights for lean application and OHS consequences. To strengthen the validity of the research outcomes as representative of developing countries, similar studies in the short- and long term can be conducted in other developing countries.

In sum, to develop more refined knowledge, more research should be focused on identifying the long-term consequences of the effects of lean on workers' health and productivity, with larger sample sizes of factories. Research is also required to determine how the factories can obtain sustainability in lean implementation. Furthermore, it would be interesting to see how productivity and OHS consequences are formed in other RMG sectors in developing countries, as well as in other types of manufacturing industries practicing lean.

5.4. RECOMMENDATIONS FOR PRACTITIONERS

Based on the results of this project, recommendations for practice can be made. In this section, I will provide my suggestions to practitioners in the RMG sector based on what I have learned from the data and experiences from the companies.

1. It is generally accepted that top management commitment is the key. My research indicated what is required to transform expressed commitment into commitment in practice by taking actions. For instance, top management must show their commitment in practice by visiting the place where lean is being implemented.

2. In countries such as Bangladesh, with a large power distance between management and workers and no tradition for involving workers, this can be a difficult task. However, this project indicated that for successful lean application, usually top management, mid-managers, and all levels of workers must be involved. It is important to listen to the workers and follow

up on their suggestions and worries. If this practice stops within 1–6 months, it this will not bring success. It should be continued until a general tendency or culture among the workers is developed.

3. Lean training is normally indicated to be another important factor. However, my study showed that formal training alone is inadequate for lean application. What is also required is on the job training after formal training. Such training must be in the local language, and if possible, more videos should be shown that are based on that specific factory's problems, indicating exactly what is wrong and what must be done. If possible, factory personnel should hire a trainer from outside because this will help to garner more attention from workers. In addition to formal training, the trainers can actively become involved with workers by visiting them on the floor to help them solve critical problems.

4. For organization of the lean application process, active team formation is required—for instance, core and operation teams. In the core team, the main responsibility is to support planning, thinking, resourcing, and being accountable for the implementation of the lean philosophy. The operation team is mainly responsible for executing the plan and programs set by the core team through selecting suitable training programs for the workers, managing the training programs, and maintaining the workers so that can adapt to the lean philosophy. Core team members should be from the owner representative, executive director-level personnel, and the production quality, HR, and compliance department heads. For the operation team, it needs to be divided into several sub-teams based on every lean tool. In addition, one industrial engineer member must be present at all times for coordinating all teams on the floor during the implementation. This will help the workers to learn new skills and improve the quality and productivity of the factory.

5. To sustain a lean environment, a learning culture must be developed. An environment may be developed where every worker and employee can share their ideas and experiences to enhance and complement each other's knowledge, competencies, and performance. The culture could be more congenial for learning if everyone is ready to take responsibility and not blame each other. The top management has a great role to play in creating a learning culture. For instance, my research suggested that to create a learning culture, some initiatives should be taken at the top-management level. For example, weekly meetings, encouraging action to be taken when new ideas are raised that are suitable, and collaboration between internal and external factories.

Worker health and working conditions must also be given the same importance as productivity, to crucially involve workers and consider OHS in lean application. Additionally, both physical and psychological factors must be emphasized with physical exercise every day on the production floor. This will help ensure more successful and sustainable lean applications in the RMG industry.

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CHAPTER 6. CONCLUSIONS

This thesis contributes to the better understanding of both productivity and OHS facilitated by lean tools in the RMG sector. In this thesis, I made this contribution by first examining the relationship between operational and OHS practices in the RMG industry, as well as from relevant literature that studied lean tools' effects on productivity and OHS. This knowledge was then used to design a lean tools application intervention with OHS consideration. Subsequently, I studied the intervention outcomes of four different factories and determined the possible mechanisms for successful lean tool applications.

In Study I, complementarities were shown between operational performances and OHS practices. The findings indicated a general trend in developing countries of how operational performance complements OHS practices and vice versa. Moreover, they indicated a positive correlation between operational and OHS practices in large factories compared with in medium-sized and smaller factories. This correlation is possibly not always the same because I found some ambiguous outcomes too. An important finding was that the institutional pressure in such countries such as Bangladesh plays the role of a proxy variable, which is why more studies in other countries are required.

In Study II, the findings from the literature review showed lean tools' effects on productivity and OHS, particularly in the RMG sector. The results of the reviewed articles indicated that lean has a positive effect on productivity, as I expected. Furthermore, for OHS consequences, the review suggested positive results, but there were also some ambiguous results. Another finding of the review was that there are no studies on the long-term effects of lean application on productivity and OHS in the RMG sector, yet these might have long-term effects on workers' health.

In Study III, the overall findings indicated positive OHS effects and productivity results, which are in line with the reviewed articles on lean tools' effects on productivity and OHS in the RMG sector. In addition, the findings indicated that the application of basic lean tools does not seem to have any negative effect on workers' health, such as muscular pain after 18 months of intervention, which is contrary to the suggestions in the general literature about lean and OHS.

In Study IV, the application of lean tools was not easy—several barriers were encountered that helped determine the successful mechanisms. Using CIMO logic, Study IV found the possible mechanisms for successful lean implementation in the RMG sector. It identified 23 possible mechanisms by analyzing intervention outcomes of four different factories. These mechanisms may contribute to lean application in other factories in a similar context and maybe even at a more general level. This study also assessed the activities of the factories in lean application in terms of following the general guidelines, which indicated how the factories were shaping themselves to achieve lean sustainability in the future.

Altogether, my results indicate that there are good possibilities for the RMG industry to meet some of its challenges, such as productivity, lead time, and compliance, through applying lean tools. This is provided that the mechanisms determined in this thesis are adhered to strongly. Regarding the integration of OHS, this also showed no negative health impacts on workers' health in the short term. However, more research is required to acquire knowledge about the long-term consequences of productivity and OHS after lean tools are applied in the RMG sector, in addition to their sustainability.

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